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Arsenic Removal from Drinking Water by Iron Removal
U.S. EPA Demonstration Project at
Vintage on the Ponds in Delavan, WI
Final Performance Evaluation Report

by

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Sally Gutierrez, Director
National Risk Management Research Laboratory

ABSTRACT

This report documents the activities performed and the results obtained for the arsenic removal treatment technology demonstration project at Vintage on the Ponds in Delavan, WI. The objectives of the project were to evaluate 1) the effectiveness of a Kinetico Macrolite® pressure filtration system in removing arsenic to meet the new arsenic maximum contaminant level (MCL) of 10 µg/L, 2) the reliability of the treatment system; 3) the required system operation and maintenance (O&M) and operator skill levels; and 4) the capital and O&M cost of the technology. The project also characterized water in the distribution system and process residuals produced by the treatment system.

The Macrolite® pressure filtration system removed arsenic via iron removal from source water. The system consisted of one 21-in × 62-in contact tank and two 21-in × 62-in pressure vessels, each containing 4.8 ft^3 of Macrolite® filter media, a spherical, low-density ceramic media manufactured by Kinetico for high-flow filtration. The treatment process included chlorine addition to oxidize As(III) to As(V) and Fe(II) to Fe(III), adsorption and/or coprecipitation of As(V) onto/with iron solids, filtration of As(V)-laden particles with the Macrolite® media, and softening (preexisting). The design flowrate was 45 gal/min (gpm) based on the well capacity, which yielded 1.8 min of contact time prior to filtration and 9.4 gpm/ft^2 of hydraulic loading to the filters. Because the actual flowrates fluctuated with the water demand from the distribution system and never exceeded 20 gpm, the minimum contact time and the maximum hydraulic loading rate would be 4.1 min and 4.2 gpm/ft^2, respectively. From July 12, 2005, through September 3, 2006, the well operated for a total of 1,072 hr at 2.6 hr/day (on average). The treatment system processed approximately 2,500,200 gal of water with an average daily demand of 5,981 gal during the study period.

Source water at Vintage on the Ponds contained 14.3 to 29.0 µg/L of total arsenic with As(III) as the predominating species at an average concentration of 16.3 µg/L. Source water also contained 997 to 2,478 µg/L of total iron present mostly in the soluble form. The average soluble iron concentration was 80 times the average soluble arsenic concentration and thus was sufficient for effective arsenic removal via iron removal.

Due to the presence of approximately 2.9 mg/L of ammonia (as N) in source water, chloramines were formed upon chlorination. Breakpoint chlorination was not performed because it would require a unrealistically high chlorine dosage (i.e., up to 22 mg/L [as Cl_2]) to obtain free chlorine and because ammonia could be easily removed by the preexisting softener units located downstream from the pressure filters.

For the first three months of system operation, little or no chlorine residual was detected in the treated water due to repeated operational problems with the chlorine feed system. After the working condition of the chlorine feed system was established in late October 2005, both chlorine dosing rates (based on chlorine tank level measurements) and total chlorine residuals (measured in the system effluent) varied widely from 1.3 to 5.9 mg/L and from <0.1 to 4.7 mg/L (as Cl_2), respectively. These values were much higher than the 1-mg/L target level recommended for the downstream softener units. The erratic chlorine residuals observed might have been caused, in part, by the on-demand system operation, which made it difficult to adjust the dosing rates.

The working condition of the chlorine addition system had direct effects on the effectiveness of the treatment system. Of the 14 arsenic speciation sampling events that took place, there were two where the chlorine injection system did not work properly. Under the circumstances, soluble Fe(II) and As(III) were either not oxidized or only partially oxidized, resulting in elevated soluble iron and soluble As(III)

levels after Macrolite® filtration. For the other 12 events where the chlorine addition system was in good working order, soluble As(III) concentrations were reduced to 4.6 μg/L after the contact tank and then to 2.9 μg/L after the pressure filters. Meanwhile, particulate arsenic concentrations increased to 10.8 μg/L after the contact tank and then decreased to 1.2 μg/L after the pressure filters (except for one sampling event where particulate arsenic breakthrough was observed due to a system backwash failure). As expected, total arsenic concentrations increased with total iron concentrations in the filter effluent. Soluble iron levels were reduced to an average of 39 μg/L after the pressure filters.

Due to the presence of chloramines, incomplete As(III) and Fe(II) oxidation was observed, with as much as 4.6 and 429 μg/L (on average) of As(III) and Fe(II), respectively, measured after the contract tank. Additional contact time in the pressure filters appeared to have enhanced oxidation of As(III) and Fe(II), reducing their concentrations to 2.9 and 39 μg/L (on average), respectively, in the filter effluent.

Total manganese concentrations averaged 19.2 μg/L in source water, existing primarily in the soluble form as Mn(II). Manganese remained in the soluble form in the treated water at levels ranging from 16.1 to 20.8 μg/L, indicating insignificant oxidation of manganese by chloramines. Soluble Mn(II) was almost completely removed by the downstream softener units.

During the performance evaluation study, the pressure filters were backwashed 102 times using chlorinated water from the contact tank. Each backwash generated approximately 360 gal of wastewater. Backwash wastewater was sampled nine times, including two grab samples and seven composite samples. The composite samples were taken from a side stream of the backwash effluent, which, presumably, was more representative of the overall wastewater quality. The analyses of the composite samples showed 11.7 to 322 μg/L of total arsenic, 0.27 to 37.1 mg/L of total iron, and 16.5 to 32.9 μg/L of total manganese. Total suspended solids (TSS) levels in the backwash wastewater were uncharacteristically low at 13.2 mg/L (on average), most likely due to insufficient mixing of solids/water mixtures before sampling.

Comparison of the distribution system water sampling results before and after system startup showed a decrease in arsenic, iron, and manganese levels at all three sampling locations. Total arsenic levels in the distribution system ranged from 3.1 to 23.3 μg/L, which, although slightly higher, mirrored the total arsenic levels in filter effluent. Neither lead nor copper concentrations appeared to have been affected by the operation of the system.

The capital investment cost was $60,500, which included $19,790 for equipment, $20,580 for engineering, and $20,130 for installation. Using the system's rated capacity of 45 gal/min (gpm) (64,800 gal/day [gpd]), the capital cost was $1,344/gpm ($0.93/gpd).

The O&M cost for the system included only incremental cost associated with the chemical supply, electricity consumption, and labor. The O&M cost was estimated at $0.26/1,000 gal.

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ABBREVIATIONS AND ACRONYMS

Δp	differential pressure
AAL	American Analytical Laboratories
Al	aluminum
AM	adsorptive media
As	arsenic
ATS	Aquatic Treatment Systems
AWWA	American Water Works Association
bgs	below ground surface
C/F	coagulation/filtration
Ca	calcium
Cl	chlorine
Cu	copper
DO	dissolved oxygen
DPD	N,N-diethyl-p-phenylene diamine
EPA	U.S. Environmental Protection Agency
F	fluoride
Fe	iron
FRP	fiberglass reinforced plastic
gpd	gal per day
gpm	gal per minute
HIX	hybrid ion exchanger
hp	horsepower
HR	high range
ICP-MS	inductively coupled plasma-mass spectrometry
IX	ion exchange
LCR	Lead and Copper Rule
MCL	maximum contaminant level
MDL	method detection limit
MEI	Magnesium Elektron, Inc.;
Mg	magnesium
Mn	manganese
MSDS	Material Safety Data Sheet
Na	sodium
NA	not applicable
NaClO	sodium hypochlorite
NRMRL	National Risk Management Research Laboratory
NTU	nephelometric turbidity units

O&M	operation and maintenance
ORD	Office of Research and Development
ORP	oxidation-reduction potential
P&ID	piping and instrumentation diagrams
POU	point-of-use
psi	pounds per square inch
PVC	polyvinyl chloride
QA	quality assurance
QAPP	quality assurance project plan
QA/QC	quality assurance/quality control
RO	reverse osmosis
RPD	relative percent difference
SDWA	Safe Drinking Water Act
STS	Severn Trent Services
SMCL	Secondary Maximum Contaminant Level
TDH	total dynamic head
TDS	total dissolved solids
TOC	total organic carbon
TSS	total suspended solids
U	uranium
V	vanadium
WDNR	Wisconsin Department of Natural Resources

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Ms. Tien Shiao, who is currently pursuing a Master's degree at Yale University, was the Battelle Study Lead for this demonstration project.

Section 1.0: INTRODUCTION

1.1 Background

The Safe Drinking Water Act (SDWA) mandates that U.S. Environmental Protection Agency (EPA) identify and regulate drinking water contaminants that may have adverse human health effects and that are known or anticipated to occur in public water supply systems. In 1975 under the SDWA, EPA established a maximum contaminant level (MCL) for arsenic at 0.05 mg/L. Amended in 1996, the SDWA required that EPA develop an arsenic research strategy and publish a proposal to revise the arsenic MCL by January 2000. On January 18, 2001, EPA finalized the arsenic MCL at 0.01 mg/L (EPA, 2001). In order to clarify the implementation of the original rule, EPA revised the rule on March 25, 2003, to express the MCL as 0.010 mg/L (10 µg/L) (EPA, 2003). The final rule requires all community and non-transient, non-community water systems to comply with the new standard by January 23, 2006.

In October 2001, EPA announced an initiative for additional research and development of cost-effective technologies to help small community water systems (<10,000 customers) meet the new arsenic standard and to provide technical assistance to operators of small systems in order to reduce compliance costs. As part of this Arsenic Rule Implementation Research Program, EPA's Office of Research and Development (ORD) proposed a project to conduct a series of full-scale, on-site demonstrations of arsenic removal technologies, process modifications, and engineering approaches applicable to small systems. Shortly thereafter, an announcement was published in the *Federal Register* requesting water utilities interested in participating in Round 1 of this EPA-sponsored demonstration program to provide information on their water systems. In June 2002, EPA selected 17 out of 115 sites to host the demonstration studies.

In September 2002, EPA solicited proposals from engineering firms and vendors for cost-effective arsenic removal treatment technologies for the 17 host sites. EPA received 70 technical proposals for the 17 host sites, with each site receiving one to six proposals. In April 2003, an independent technical panel reviewed the proposals and provided its recommendations to EPA on the technologies that it determined were acceptable for the demonstration at each site. Because of funding limitations and other technical reasons, only 12 of the 17 sites were selected for the demonstration project. Using the information provided by the review panel, EPA, in cooperation with the host sites and the drinking water programs of the respective states, selected one technical proposal for each site.

In 2003, EPA initiated Round 2 arsenic technology demonstration projects that were partially funded with Congressional add-on funding to the EPA budget. In June 2003, EPA selected 32 potential demonstration sites and the community water system at Vintage on the Ponds in Delavan, WI was one of those selected.

In September 2003, EPA, again, solicited proposals from engineering firms and vendors for arsenic removal technologies. EPA received 148 technical proposals for the 32 host sites, with each site receiving from two to eight proposals. In April 2004, another technical panel was convened by EPA to review the proposals and provide recommendations to EPA with the number of proposals per site ranging from none (for two sites) to a maximum of four. The final selection of the treatment technology at the sites that received at least one proposal was made, again, through a joint effort by EPA, the state regulators, and the host site. Since then, four sites have withdrawn from the demonstration program, reducing the number of sites to 28. Kinetico's Macrolite® Arsenic Removal Technology was selected for demonstration at the Vintage on the Ponds facility in September 2004.

As of April 2009, 39 of the 40 systems were operational and the performance evaluation of 32 systems was completed.

1.2 Treatment Technologies for Arsenic Removal

The technologies selected for the Round 1 and Round 2 demonstration host sites include 25 adsorptive media (AM) systems (the Oregon Institute of Technology [OIT] site has three AM systems), 13 coagulation/filtration (C/F) systems, two ion exchange (IX) systems, and 17 point-of-use (POU) units (including nine under-the-sink reverse osmosis [RO] units at the Sunset Ranch Development site and eight AM units at the OIT site), and one system modification. Table 1-1 summarizes the locations, technologies, vendors, system flowrates, and key source water quality parameters (including As, Fe, and pH) at the 40 demonstration sites. An overview of the technology selection and system design for the 12 Round 1 demonstration sites and the associated capital costs is provided in two EPA reports (Wang et al., 2004; Chen et al., 2004), which are posted on the EPA website at http://www.epa.gov/ORD/NRMRL/wswrd/dw/arsenic/index.html.

1.3 Project Objectives

The objective of the arsenic demonstration program is to conduct 40 full-scale arsenic treatment technology demonstration studies on the removal of arsenic from drinking water supplies. The specific objectives are to:

- Evaluate the performance of the arsenic removal technologies for use on small systems.
- Determine the required system operation and maintenance (O&M) and operator skill levels.
- Characterize process residuals produced by the technologies.
- Determine the capital and O&M cost of the technologies.

This report summarizes the performance of the Kinetico Macrolite® Arsenic Removal system at Vintage on the Ponds in Delavan, WI from July 12, 2005, through September 3, 2006. The types of data collected included system operation, water quality (both across the treatment train and in the distribution system), residuals, and capital and preliminary O&M cost.

Table 1-1. Summary of Round 1 and Round 2 Arsenic Removal Demonstration Sites

Demonstration Location	Site Name	Technology (Media)	Vendor	Design Flowrate (gpm)	Source Water Quality		
					As (µg/L)	Fe (µg/L)	pH (S.U.)
Northeast/Ohio							
Wales, ME	Springbrook Mobile Home Park	AM (A/I Complex)	ATS	14	38[a]	<25	8.6
Bow, NH	White Rock Water Company	AM (G2)	ADI	70[b]	39	<25	7.7
Goffstown, NH	Orchard Highlands Subdivision	AM (E33)	AdEdge	10	33	<25	6.9
Rollinsford, NH	Rollinsford Water and Sewer District	AM (E33)	AdEdge	100	36[a]	46	8.2
Dummerston, VT	Charette Mobile Home Park	AM (A/I Complex)	ATS	22	30	<25	7.9
Felton, DE	Town of Felton	C/F (Macrolite)	Kinetico	375	30[a]	48	8.2
Stevensville, MD	Queen Anne's County	AM (E33)	STS	300	19[a]	270[c]	7.3
Houghton, NY[d]	Town of Caneadea	C/F (Macrolite)	Kinetico	550	27[a]	1,806[c]	7.6
Newark, OH	Buckeye Lake Head Start Building	AM (ARM 200)	Kinetico	10	15[a]	1,312[c]	7.6
Springfield, OH	Chateau Estates Mobile Home Park	AM (E33)	AdEdge	250[e]	25[a]	1,615[c]	7.3
Great Lakes/Interior Plains							
Brown City, MI	City of Brown City	AM (E33)	STS	640	14[a]	127[c]	7.3
Pentwater, MI	Village of Pentwater	C/F (Macrolite)	Kinetico	400	13[a]	466[c]	6.9
Sandusky, MI	City of Sandusky	C/F (Aeralater)	Siemens	340[e]	16[a]	1,387[c]	6.9
Delavan, WI	Vintage on the Ponds	C/F (Macrolite)	Kinetico	40	20[a]	1,499[c]	7.5
Greenville, WI	Town of Greenville	C/F (Macrolite)	Kinetico	375	17	7827[c]	7.3
Climax, MN	City of Climax	C/F (Macrolite)	Kinetico	140	39[a]	546[c]	7.4
Sabin, MN	City of Sabin	C/F (Macrolite)	Kinetico	250	34	1,470[c]	7.3
Sauk Centre, MN	Big Sauk Lake Mobile Home Park	C/F (Macrolite)	Kinetico	20	25[a]	3,078[c]	7.1
Stewart, MN	City of Stewart	C/F&AM (E33)	AdEdge	250	42[a]	1,344[c]	7.7
Lidgerwood, ND	City of Lidgerwood	Process Modification	Kinetico	250	146[a]	1,325[c]	7.2
Midwest/Southwest							
Arnaudville, LA	United Water Systems	C/F (Macrolite)	Kinetico	770[e]	35[a]	2,068[c]	7.0
Alvin, TX	Oak Manor Municipal Utility District	AM (E33)	STS	150	19[a]	95	7.8
Bruni, TX	Webb Consolidated Independent School District	AM (E33)	AdEdge	40	56[a]	<25	8.0
Wellman, TX	City of Wellman	AM (E33)	AdEdge	100	45	<25	7.7
Anthony, NM	Desert Sands Mutual Domestic Water Consumers Association	AM (E33)	STS	320	23[a]	39	7.7
Nambe Pueblo, NM	Nambe Pueblo Tribe	AM (E33)	AdEdge	145	33	<25	8.5
Taos, NM	Town of Taos	AM (E33)	STS	450	14	59	9.5
Rimrock, AZ	Arizona Water Company	AM (E33)	AdEdge	90[b]	50	170	7.2
Tohono O'odham Nation, AZ	Tohono O'odham Utility Authority	AM (E33)	AdEdge	50	32	<25	8.2
Valley Vista, AZ	Arizona Water Company	AM (AAFS50/ARM 200)	Kinetico	37	41	<25	7.8

Table 1-1. Summary of Round 1 and Round 2 Arsenic Removal Demonstration Sites (Continued)

Demonstration Location	Site Name	Technology (Media)	Vendor	Design Flowrate (gpm)	Source Water Quality As (µg/L)	Fe (µg/L)	pH (S.U.)
Far West							
Three Forks, MT	City of Three Forks	C/F (Macrolite)	Kinetico	250	64	<25	7.5
Fruitland, ID	City of Fruitland	IX (A300E)	Kinetico	250	44	<25	7.4
Homedale, ID	Sunset Ranch Development	POU RO[f]	Kinetico	75 gpd	52	134	7.5
Okanogan, WA	City of Okanogan	C/F (Electromedia-I)	Filtronics	750	18	69[c]	8.0
Klamath Falls, OR	Oregon Institute of Technology	POE AM (Adsorbsia/ARM 200/ArsenX[np]) and POU AM (ARM 200)[g]	Kinetico	60/60/30	33	<25	7.9
Vale, OR	City of Vale	IX (Arsenex II)	Kinetico	525	17	<25	7.5
Reno, NV	South Truckee Meadows General Improvement District	AM (GFH/Kemiron)	Siemens	350	39	<25	7.4
Susanville, CA	Richmond School District	AM (A/I Complex)	ATS	12	37[a]	125	7.5
Lake Isabella, CA	Upper Bodfish Well CH2-A	AM (HIX)	VEETech	50	35	125	7.5
Tehachapi, CA	Golden Hills Community Service District	AM (Isolux)	MEI	150	15	<25	6.9

AM = adsorptive media process; C/F = coagulation/filtration; HIX = hybrid ion exchanger; IX = ion exchange process; RO = reverse osmosis
ATS = Aquatic Treatment Systems; MEI = Magnesium Elektron, Inc.; STS = Severn Trent Services

(a) Arsenic existing mostly as As(III).
(b) Design flowrate reduced by 50% due to system reconfiguration from parallel to series operation.
(c) Iron existing mostly as Fe(II).
(d) Withdrew from program in 2007. Selected originally to replace Village of Lyman, NE site, which withdrew from program in June 2006.
(e) Facilities upgraded systems in Springfield, OH from 150 to 250 gpm, Sandusky, MI from 210 to 340 gpm, and Arnaudville, LA from 385 to 770 gpm.
(f) Including nine residential units.
(g) Including eight under-the-sink units.

Section 2.0: SUMMARY AND CONCLUSIONS

Based on the information collected during the first six months of system operation, the following conclusions were made relating to the overall objectives of the treatment technology demonstration study.

Performance of the arsenic removal technology for use on small systems:

- The Macrolite® pressure filters effectively removed arsenic to below the 10-µg/L MCL provided that the chlorine addition system was in good working condition. Occasional exceedances were observed in the filter effluent due mainly to particulate arsenic and particulate iron breakthrough from the filters. Due to the on-demand system configuration, the pressure filters operated at a maximum hydraulic loading rate of 4.2 gpm/ft^2, about 45% of the design value.
- The presence of 2.9 mg/L of ammonia (as N) in source water presented a challenge to soluble As(III) and soluble Fe(II) oxidation with chlorine. Formation of chloramines significantly hampered their oxidation, leaving as much as 4.6 and 429 µg/L (on average) of As(III) and Fe(II), respectively, after the contact tank. (Note that, depending on on-demand flowrates, the contact tank provided at least 4.1 min of contact time before entering the pressure filters.) Prolonged contact times through the pressure filters appeared to be useful in improving As(III) and Fe(II) oxidation, reducing their concentrations to 2.9 and 39 µg/L (on average), respectively, after the pressure filters.
- Arsenic speciation was a valuable tool to assess the effectiveness of As(III) oxidation.
- Manganese was not removed by the Macrolite® pressure filters. Soluble Mn(II) remained to be soluble upon chlorination, indicating ineffective oxidation by chloramines.
- Decreases in arsenic, iron, and manganese levels were observed at all three distribution system sampling locations. Total arsenic levels in the distribution system mirrored those in the filter effluent. Neither lead nor copper concentrations were affected by the operation of the system.

Required system O&M and operator skill levels:

- Repeated operational problems with the chlorine addition system were encountered during the first three months of system operation. The problems encountered included failures of the feed pump and the chlorine injector, leaks of copper pipe due to its incompatibility with the 12.5% NaOCl solution, and erratic and inconsistent chlorine residual measurements.
- The Macrolite® filtration system had no unscheduled downtime; however, it was operated without any chlorine addition for 63 days.
- The typical daily demand on the operator to maintain the system was about 5 min. However, the chlorine feed system had to be constantly monitored and adjusted to ensure proper working conditions. Additional time was required to troubleshoot and maintain the chemical feed system.

- Operating the chlorine feed system required skills to handle NaOCl solutions, chemical feed pump, and chlorine residual measurements, and may be challenging to persons with no prior experience.

Process residuals produced by the technology:

- Depending on water demand, the pressure filters were backwashed approximately once a day to once several days. Backwashing was triggered by a throughput setting of 18,000 gal; however, some variations were observed during the study period.
- Each backwash produced approximately 360 gal of wastewater per vessel.

Cost of the technology:

- The unit capital cost was \$0.24/1,000 gal if the system operates at 100% utilization rate. The system's real unit cost was \$2.61/1,000 gal, based on an annual production of 2,200,000 gal of water by the system.
- The O&M cost was \$0.26/1,000 gal, based on labor, chemical usage, and electricity consumption.

Section 3.0: MATERIALS AND METHODS

3.1 General Project Approach

Following the predemonstration activities summarized in Table 3-1, the performance evaluation of the Macrolite® treatment system began on July 12, 2005. Table 3-2 summarizes the types of data collected and considered as part of the technology evaluation process. The overall system performance was evaluated based on its ability to consistently remove arsenic to below the target MCL of 10 µg/L through the collection of water samples across the treatment train. The reliability of the system was evaluated by tracking the unscheduled system downtime and frequency and extent of repair and replacement. The unscheduled downtime and repair information were recorded by the plant operator on a Repair and Maintenance Log Sheet.

Table 3-1. Predemonstration Study Activities and Completion Dates

Activity	Date
Introductory Meeting Held	09/20/04
Request for Quotation Issued to Vendor	02/22/05
Vendor Quotation Received	03/03/05
Purchase Order Established	03/30/05
Letter of Understanding Issued	02/16/05
Letter Report Issued	05/24/05
Engineering Package Submitted WDNR	04/25/05
Permit Issued by WDNR	06/10/05
Study Plan Issued	06/21/05
Macrolite® Unit Shipped by Kinetico	06/17/05
System Installation Completed	07/01/05
System Shakedown Completed	07/12/05
Performance Evaluation Begun	07/12/05

WDNR = Wisconsin Department of Natural Resources

Table 3-2. Evaluation Objectives and Supporting Data Collection Activities

Evaluation Objective	Data Collection
Performance	-Ability to consistently meet 10-µg/L arsenic MCL in treated water
Reliability	-Unscheduled system downtime -Frequency and extent of repairs including a description of problems, materials and supplies needed, and associated labor and cost
System O&M and Operator Skill Requirements	-Pre- and post-treatment requirements -Level of automation for system operation and data collection -Staffing requirements including number of operators and laborers -Task analysis of preventive maintenance including number, frequency, and complexity of tasks -Chemical handling and inventory requirements -General knowledge needed for relevant chemical processes and health and safety practices
Residual Management	-Quantity and characteristics of aqueous and solid residuals generated by system operation
Cost-Effectiveness	-Capital cost for equipment, engineering, and installation -O&M cost for chemical usage, electricity consumption, and labor

The O&M and operator skill requirements were evaluated based on a combination of quantitative data and qualitative considerations, including the need for pre- and/or post-treatment, level of system automation, extent of preventative maintenance activities, frequency of chemical and/or media handling and inventory, and general knowledge needed for relevant chemical processes and related health and safety practices. The staffing requirements for system operation were recorded on an Operator Labor Hour Log Sheet.

The quantity of aqueous and solid residuals generated was estimated by tracking the volume of backwash water produced during each backwash cycle. Backwash water was sampled and analyzed for chemical characteristics.

The cost of the system was evaluated based on the capital cost per gal/min (gpm) (or gal/day [gpd]) of design capacity and the O&M cost per 1,000 gal of water treated. This task required tracking the capital cost for equipment, engineering, and installation, as well as the O&M cost for chemical supply, electricity usage, and labor.

3.2 System O&M and Cost Data Collection

The plant operator performed daily, weekly, and monthly system O&M and data collection according to instructions provided by the vendor and Battelle. On a daily basis, with the exception of Saturdays and Sundays, the plant operator recorded system operational data, such as pressure, flowrate, totalizer, and hour meter readings on a Daily System Operation Log Sheet; checked the sodium hypochlorite (NaClO) tank level; and conducted visual inspections to ensure normal system operations. If any problems occurred, the plant operator contacted the Battelle Study Lead, who determined if the vendor should be contacted for troubleshooting. The plant operator recorded all relevant information, including the problem encountered, course of action taken, materials and supplies used, and associated cost and labor incurred, on a Repair and Maintenance Log Sheet. On a weekly basis, the plant operator measured several water quality parameters on-site, including temperature, pH, dissolved oxygen (DO), oxidation-reduction potential (ORP), and residual chlorine, and recorded the data on an On-Site Water Quality Parameters Log Sheet. Monthly backwash data also were recorded on a Backwash Log Sheet.

The capital cost for the arsenic removal system consisted of the cost for equipment, site engineering, and system installation. The O&M cost consisted of the cost for chemical usage, electricity consumption, and labor. Consumption of NaClO was tracked on the Daily System Operation Log Sheet. Electricity consumption was determined from utility bills. Labor for various activities, such as routine system O&M, troubleshooting and repairs, and demonstration-related work, was tracked using an Operator Labor Hour Log Sheet. The routine system O&M included activities such as completing field logs, replenishing the NaOCl solution, ordering supplies, performing system inspections, and others as recommended by the vendor. The labor for demonstration-related work, including activities such as performing field measurements, collecting and shipping samples, and communicating with the Battelle Study Lead and the vendor, was recorded, but not used for the cost analysis.

3.3 Sample Collection Procedures and Schedules

To evaluate system performance, samples were collected at the wellhead, across the treatment system, during Macrolite® filter backwash, and from the distribution system. The sampling schedules and analytes measured during each sampling event are listed in Table 3-3. In addition, Figure 3-1 presents a flow diagram of the treatment system along with the analytes and schedules at each sampling location.

Table 3-3. Sampling Schedule and Analyses

Sample Type	Sample Locations[(a)]	No. of Samples	Frequency	Analytes	Date(s) Samples Collected
Source Water	IN	1	Once (during initial site visit)	On-site: pH, temperature, DO, and ORP Off-site: As(III), As(V), As (total and soluble), Fe (total and soluble), Mn (total and soluble), U (total and soluble), V (total and soluble), Na, Ca, Mg, Cl, F, NO_3, NO_2, NH_3, SO_4, SiO_2, PO_4, turbidity, alkalinity, TDS, and TOC	Table 4-1
Treatment Plant Water	IN, AC, TA, TB	4	Weekly	On-site: pH, temperature, DO, ORP, and Cl_2 (total and free)[(b)] Off-site: As (total), Fe (total), Mn (total), SiO_2, PO_4/P (total), turbidity, and alkalinity	Appendix B
	IN, AC, TT	3	Monthly	Same as weekly analytes shown above plus the following: Off-site: As (soluble), As(III), As(V), Fe (soluble), Mn (soluble), Ca, Mg, F, NO_3, NH_3, SO_4, and TOC	Appendix B
Backwash Wastewater	BW	2	Monthly	As (total and soluble), Fe (total and soluble), Mn (total and soluble), pH, turbidity ,TDS, and TSS	Table 4-9
Backwash Solids	BW	1	Once	Total Al, As, Ba, Ca, Cd, Cu, Fe, Mg, Mn, Ni, P, Pb, Sb, Si, V, and Zn	Table 4-10
Distribution Water	Two LCR and One non-LCR Locations	3	Monthly	As (total), Fe (total), Mn (total), Cu, Pb, pH, alkalinity	Table 4-11

(a) Abbreviation corresponding to sample location in Figure 3-1, i.e., IN = at wellhead; AC = after contact tank; TA = after Vessel A, TB = after Vessel B; TT = after Vessels A and B combined; BW = at backwash discharge line.
(b) Only taken at AC, TA, TB, and TT.

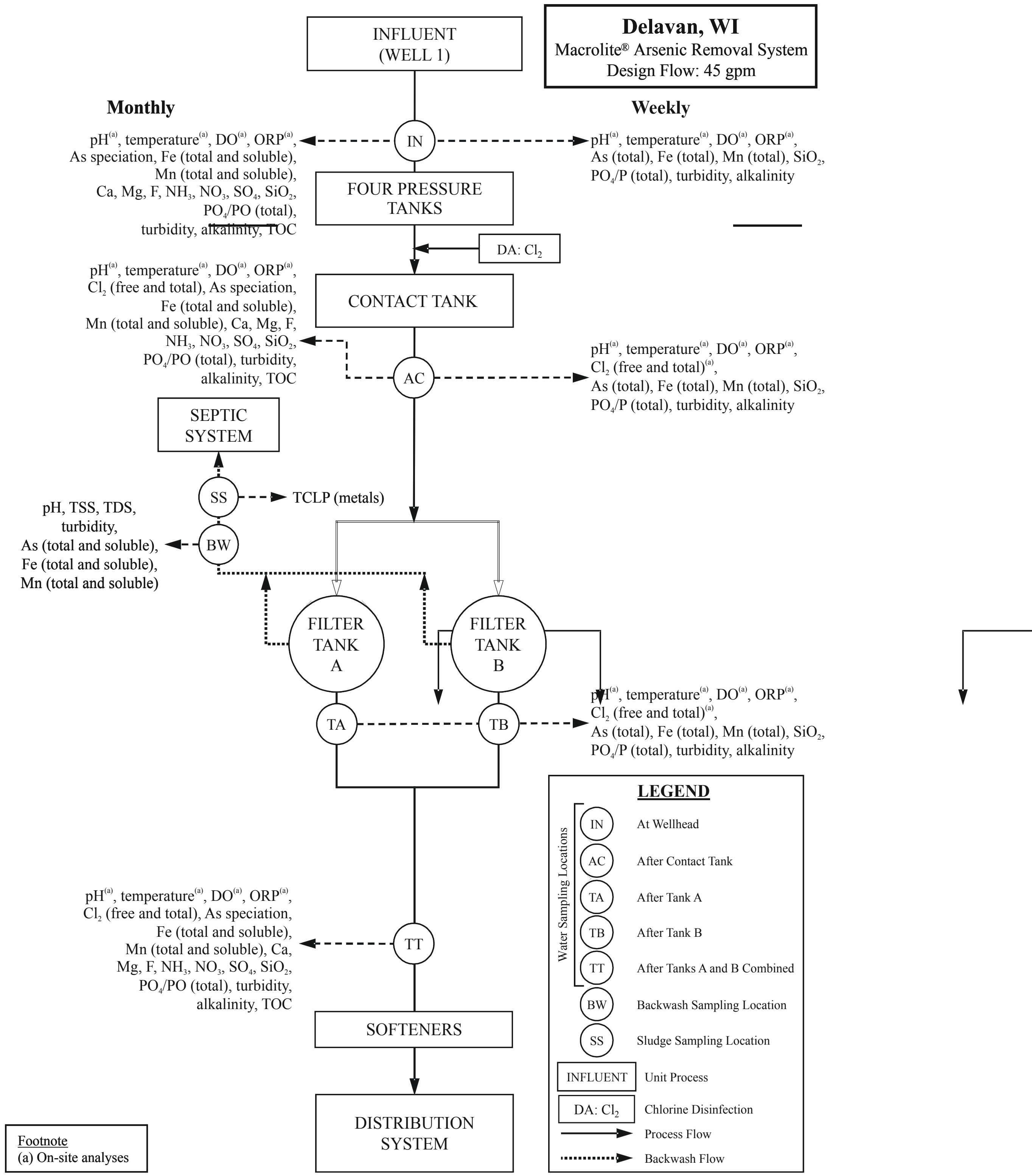

Figure 3-1. Process Flow Diagram and Sampling Locations

Specific sampling requirements for analytical methods, sample volumes, containers, preservation, and holding times are presented in Table 4-1 of the EPA-endorsed Quality Assurance Project Plan (QAPP) (Battelle, 2004). The procedure for arsenic speciation is described in Appendix A of the QAPP.

3.3.1 Source Water. During the initial visit to the site, one set of source water samples was collected and speciated using an arsenic speciation kit. Additional samples were collected after the softeners to assess the working condition of the softener. Each sample tap was flushed for several minutes before sampling; special care was taken to avoid agitation, which might cause unwanted oxidation. Analytes for the source water samples are listed in Table 3-3.

3.3.2 Treatment Plant Water. During the system performance evaluation, the plant operator collected samples weekly, on a four-week cycle, for on- and off-site analyses. For the first week of each four-week cycle, samples taken at the wellhead (IN), after the contact tank (AC), and after Vessels A and B combined (TT), were speciated on-site and analyzed for the analytes listed in Table 3-3 for monthly treatment plant water. For the next three weeks, samples were collected at IN, AC, after Vessel A (TA), and after Vessel B (TB) and analyzed for the analytes listed in Table 3-3 for the weekly treatment plant water.

Treatment plant water samples were not taken during the weeks of November 21 and December 19 and 26, 2005, due to Thanksgiving and Christmas holidays. Treatment plant water samples were not taken, either, during the weeks of July 3 and 24 and August 7 and 21, 2006, due to reduced sampling efforts by the end of the study period.

3.3.3 Backwash Wastewater. Backwash wastewater samples were collected on nine occasions monthly from each pressure filter by the plant operator. The samples taken on November 29, 2005, were not representative of the actual backwash wastewater quality because the pressure filters had just been backwashed three times in a row due to an operational error (see Section 4.5.2) and, therefore, not included in this report.

For the first two sampling events, one grab sample was collected during the backwash of each pressure filter from the sample tap located on the backwash wastewater discharge line, but before the backwash totalizer. Unfiltered samples were measured on-site for pH and off-site for total dissolved solids (TDS) and turbidity. Filtered samples using 0.45-µm disc filters were analyzed for soluble arsenic, iron, and manganese. Starting in November 2005, the backwash wastewater sampling procedure was modified to include the collection of composite samples for total As, Fe, and Mn as well as total suspended solids (TSS) analyses. This modified procedure involved diverting a portion of backwash wastewater at approximately 1 gpm into a clean, 32-gal plastic container over the duration of the backwash for each filter. After the content in the container was thoroughly mixed, composite samples were collected and/or filtered on-site with 0.45-µm filters. Analytes for the backwash wastewater samples are listed in Table 3-3.

3.3.4 Residual Solids. Residual solids produced from backwash were collected once from the backwash discharge line for Vessel B on July 13, 2006 and analyzed for the analytes listed in Table 3-3.

3.3.5 Distribution System Water. Samples were collected from the distribution system by the plant operator to determine the impact of the arsenic treatment system on the water chemistry in the distribution system, specifically, the arsenic, lead, and copper levels. Prior to system startup from March to June 2005, four sets of monthly baseline water samples were collected from three sampling locations within the distribution system. The three sampling locations selected initially included one tap each in the dining room, the shower room in A Wing, and the large suite in B Wing, which were among the five Lead and Copper Rule (LCR) sampling locatioins at Vintage on the Ponds. However, due to water usage at night from the tap in the dining room, this sampling location was replaced with a tap in the second floor guest room (which is a non-LCR location) starting from the second baseline sampling event. Following system startup, distribution system sampling continued on a monthly basis at the same three locations. Note that all sampling locations were located downstream from two water softeners both before and after the startup of the Macrolite® pressure filters.

The operator collected samples following an instruction sheet developed according to the *Lead and Copper Monitoring and Reporting Guidance for Public Water Systems* (EPA, 2002). The dates and times of last water usage before sampling and sample collection were recorded for calculations of the stagnation time. All first draw samples were collected from respective cold-water faucets that had not been used for at least 6 hr to ensure that stagnant water was sampled. Analytes for the baseline samples coincided with the monthly distribution system water samples as described in Table 3-3. Arsenic speciation was not performed for the distribution water samples.

3.4 Sampling Logistics

3.4.1 Preparation of Arsenic Speciation Kits. The arsenic field speciation method uses an anion exchange resin column to separate the soluble arsenic species, As(V) and As(III) (Edwards et al., 1998). Resin columns were prepared in batches at Battelle laboratories according to the procedures detailed in Appendix A of the EPA-endorsed QAPP (Battelle, 2004).

3.4.2 Preparation of Sampling Coolers. For each sampling event, a sample cooler was prepared with the appropriate number and type of sample bottles, disc filters, and/or speciation kits. All sample bottles were new and contained appropriate preservatives. Each sample bottle was affixed with a pre-printed, colored-coded label consisting of the sample identification (ID), date and time of sample collection, collector's name, site location, sample destination, analysis required, and preservative. The sample ID consisted of a two-letter code for the specific water facility, sampling date, a two-letter code for a specific sampling location, and a one-letter code designating the arsenic speciation bottle (if necessary). The sampling locations at the treatment plant were color-coded for easy identification. The labeled bottles for each sampling locations were placed in separate Ziplock™ bags and packed in the cooler.

In addition, all sampling- and shipping-related materials, such as disposable gloves, sampling instructions, chain-of-custody forms, prepaid/addressed FedEx air bills, and bubble wrap, were included. The chain-of-custody forms and air bills were complete except for the operator's signature and the sample dates and times. After preparation, the sample cooler was sent to the site via FedEx for the following week's sampling event.

3.4.3 Sample Shipping and Handling. After sample collection, samples for off-site analyses were packed carefully in the original coolers with wet ice and shipped to Battelle. Upon receipt, the sample custodian verified that all samples indicated on the chain-of-custody forms were included and intact. Sample IDs were checked against the chain-of-custody forms, and the samples were logged into the laboratory sample receipt log. Discrepancies noted by the sample custodian were addressed with the plant operator by the Battelle Study Lead.

Samples for metal analyses were stored at Battelle's inductively coupled plasma-mass spectrometry (ICP-MS) Laboratory. Samples for other water quality analyses were packed in separate coolers and picked up by couriers from American Analytical Laboratories (AAL) in Columbus, OH and TCCI Laboratories in New Lexington, OH, both of which were under contract with Battelle for this demonstration study. The chain-of-custody forms remained with the samples from the time of preparation through analysis and final disposition. All samples were archived by the appropriate laboratories for the respective duration of the required hold time and disposed of properly thereafter.

3.5 Analytical Procedures

The analytical procedures described in Section 4.0 of the EPA-endorsed QAPP (Battelle, 2004) were followed by Battelle ICP-MS, AAL, and TCCI Laboratories. Laboratory quality assurance/quality control (QA/QC) of all methods followed the prescribed guidelines. Data quality in terms of precision, accuracy, method detection limits (MDL), and completeness met the criteria established in the QAPP (i.e., relative percent difference [RPD] of 20%, percent recovery of 80 to 120%, and completeness of 80%). The quality assurance (QA) data associated with each analyte will be presented and evaluated in a QA/QC Summary Report to be prepared under separate cover upon completion of the Arsenic Demonstration Project.

Field measurements of pH, temperature, DO, and ORP were conducted by the plant operator using a VWR Symphony SP90M5 Handheld Multimeter, which was calibrated for pH and DO prior to use following the procedures provided in the user's manual. The ORP probe also was checked for accuracy by measuring the ORP of a standard solution and comparing it to the expected value. The plant operator collected a water sample in a clean, plastic beaker and placed the Symphony SP90M5 probe in the beaker until a stable value was obtained. The plant operator also performed free and total chlorine measurements using Hach chlorine test kits following the user's manual.

Section 4.0: RESULTS AND DISCUSSION

4.1 Facility Description and Preexisting Treatment System Infrastructure

Vintage on the Ponds is a nursing home facility located at N4901 Dam Road, Delavan, WI. Well No. 1 (see Figure 4-1 for the preexisting pump house) supplies water to approximately 52 residents. Based on the water usage data recorded from November 12, 2003, through February 21, 2005, the average daily demand was approximately 6,400 gpd and the peak daily demand was 23,500 gpd.

Well No. 1 went online on October 15, 1995, with a depth of 350 ft below ground surface (bgs) in a limestone formation. It had a 10-in-diameter borehole lined with a 6-in-diameter casing extending from the ground surface to 244 ft bgs and a 6-in-diameter unlined borehole extending from 244 to 350 ft bgs. The static water level was measured at approximately 45 ft bgs based on the water level readings taken at the time of well installation in 1995. Installed on a 105-ft drop pipe, a 5-horsepower (hp) submersible pump supplied water at 41.5 gpm against a 115.4-ft (or 50-lb/in^2 [psi]) total dynamic head (TDH). To meet the daily demand, the well pump was operated intermittently based on the high and low pressure settings in a set of four pressure tanks, with the well pump on at 40 psi and off at 60 psi. Figure 4-2 shows the piping from the wellhead to the four pressure tanks located within the basement of the nursing home.

Water from the pressure tanks was treated with a 29TMDM-300 softener system consisting of two 24-in × 72-in tanks each containing 10 ft^3 of Ionac C-249 cation exchange resin manufactured by Sybron Chemicals (see Figure 4-3). The system was designed for a flowrate of 68 gpm and a peak flowrate of 91 gpm. The two softener units operated alternately, i.e., one unit was in service while the other was on standby. Each softener unit was regenerated after treating about 6,000 gal of water (approximately daily), which was tracked by a 2-in mechanical meter located upstream of the softener unit. When the meter called for regeneration, the unit in service went into regeneration, and the unit on standby came online. Upon completion of regeneration, the unit went into standby until another 6,000 gal of water had been treated. Prior to this demonstration project, there was no chlorination at the wellhead.

4.1.1 Source Water Quality. Source water samples were collected on September 20, 2004, before and after the softeners, as discussed in Section 3.3.1. The results of source water analyses, along with those provided by the facility to EPA for the demonstration site selection and those independently collected and analyzed by EPA, WDNR, and the vendor are presented in Table 4-1.

As shown in Table 4-1, total arsenic concentrations in source water ranged from 16.0 to 25.0 µg/L. Based on September 20, 2004, results, approximately 95% (i.e., 17.7 µg/L) of the total arsenic existed as soluble As(III). The presence of As(III) as the predominating arsenic species was consistent with the low DO and ORP readings of 1.2 mg/L and -123 mV, respectively. Iron concentrations in source water ranged from 1,499 to 2,300 µg/L with almost all existing in the soluble form. A rule of thumb is that the soluble iron concentration should be at least 20 times the soluble arsenic concentration for effective arsenic removal via iron removal (Sorg, 2002). The results from the September 20, 2004, sampling event indicated that the soluble iron level was approximately 68 times the soluble arsenic level. Therefore, no supplemental iron addition was planned. The manganese levels ranged from 19.0 to 20.2 µg/L, existing almost entirely in the soluble form. pH values of source water ranged from 7.3 to 7.7, which were within the target range of 5.5 to 8.5 for the iron removal process. Hardness ranged from 291 to 346 mg/L, silica from 14.2 to 14.6 mg/L, and sulfate from <1 mg/L to 10 mg/L.

Figure 4-1. Preexisting Well No. 1 Pump House

Figure 4-2. Preexisting Well Piping and Pressure Tanks

Figure 4-3. Preexisting Softener System

Ammonia was measured at 2.8 mg/L (as N) in raw water and reduced to 0.4 mg/L after softening. Since the treatment system was to be placed upstream of the softener, the presence of ammonia in raw water had a significant impact on chlorination. When chlorine is added to raw water, it oxidizes Fe(II), As(III), and other reducing species and reacts with ammonia to form chloramines according to the following equations:

$$HOCl + NH_3 \rightarrow NH_2Cl \text{ (monochloramine)} + H_2O$$

$$HOCl + NH_2Cl \rightarrow NHCl_2 \text{ (dichloramine)} + H_2O$$

$$HOCl + NHCl_2 \rightarrow NCl_3 \text{ (trichloramine)} + H_2O$$

The formation of chloramines depends upon water pH, ammonia concentration, and temperature (Clark et al., 1977). In the pH range of 4.5 to 8.5, both mono and dichloramine are formed as combined chlorine. Based on stoichiometric calculations, 1 mg/L of NH_3 (as N) reacts with 5 mg/L of HOCl (as Cl_2) to form 5 mg/L of NH_2Cl (as Cl_2). As such, 14 mg/L of HOCl (as Cl_2) would be required to react with 2.8 mg/L of NH_3 (as N) to form chloramines. Chlorine added beyond this point further oxidizes chloramines to form oxidized nitrogen compounds, such as nitrous oxide, nitrogen, and nitrogen trichloride. Upon complete oxidation of all chloramines, a "breakpoint" is reached and any additional chlorine added is present as free chlorine.

For Vintage on the Ponds, "breakpoint" chlorination was not performed because 1) it would require up to 23 mg/L of HOCl (as Cl_2), which would be expensive, and 2) any unreactive ammonia would be removed by the existing softener units before entering the distribution system. Another consideration was the adverse effect of chlorine residuals on the cationic exchange resin in the softener units. According to the manufacturer, resin life would be significantly reduced if it is exposed to over 1 mg/L of chlorine (mostly chloramines in this case). Therefore, the chlorine dosage must be carefully controlled to ensure, on one hand, effective oxidation of Fe(II) and As(III), and on the other hand, no harmful effect on the resin.

Table 4-1. Vintage on the Ponds, WI Water Quality Data

Parameter	Unit	Utility Source Water Data[(a)]	Kinetico Source Water Data	Battelle Source Water Data	Battelle Softened Water Data	WDNR Source Water Data[(b)]
Date		Not specified	10/29/03	09/20/04	09/20/04	08/08/00–02/23/05
pH		7.6	7.3	7.5	NS	7.7
Temperature	°C	NS	NS	12.7	NS	NS
DO	Mg/L	NS	NS	1.2	NS	NS
ORP	mV	NS	NS	-123	NS	NS
Total Alkalinity (as $CaCO_3$)	Mg/L	188	344	384	371	320
Hardness (as $CaCO_3$)	Mg/L	291	312	346	4.1	336–340
Turbidity	NTU	NS	NS	20.0	0.5	NS
TDS	Mg/L	NS	NS	330	358	NS
TOC	Mg/L	NS	NS	1.8	1.8	NS
Nitrate (as N)	Mg/L	NS	NS	<0.04	<0.04	<0.04
Nitrite (as N)	Mg/L	NS	NS	<0.01	<0.01	<0.01
Ammonia (as N)	Mg/L	NS	NS	2.8	0.4	NS
Chloride	Mg/L	15	1.9	<1.0	<1.0	<1.0
Fluoride	Mg/L	NS	0.20	0.27	0.33	0.26–0.31
Sulfate	Mg/L	10	<4.0	<1.0	<1.0	NS
Silica (as SiO_2)	Mg/L	NS	14.2	14.3	14.6	NS
Orthophosphate (as P)	Mg/L	NS	<0.5	<0.06	<0.06	NS
As (total)	µg/L	25.0	19.0	20.1	19.1	16.0–23.0
As (soluble)	µg/L	NS	NS	20.5	18.7	NS
As (particulate)	µg/L	NS	NS	<0.1	0.4	NS
As(III)	µg/L	NS	NS	19.1	17.7	NS
As(V)	µg/L	NS	NS	1.4	1.0	NS
Fe (total)	µg/L	1,500	1,600	1,499	<25	2,300
Fe (soluble)	µg/L	NS	NS	1,400	<25	NS
Mn (total)	µg/L	NS	20.0	20.2	0.3	19.0
Mn (soluble)	µg/L	NS	NS	18.3	<0.1	NS
U (total)	µg/L	NS	NS	<0.1	<0.1	NS
U (soluble)	µg/L	NS	NS	<0.1	<0.1	NS
V (total)	µg/L	NS	NS	0.3	0.4	NS
V (soluble)	µg/L	NS	NS	0.1	0.1	NS
Na (total)	Mg/L	10	11.0	12.4	181	12.0–160
Ca (soluble)	Mg/L	NS	62.5	71.4	0.4	72.0
Mg (total)	Mg/L	NS	36.0	40.7	0.08	38.0
Radium-226	pCi/L	NS	NS	NS	NS	0.6
Radium-228	pCi/L	NS	NS	NS	NS	0.9

(a) Provided to EPA for site selection.
(b) Both compliance and source water samples collected before the softener.
NS = not sampled

4.1.2 Distribution System and Treated Water Quality. The distribution system was supplied by Well No. 1 only. According to a certified utility operator, the distribution system consisted primarily of copper piping ranging from ½ to 2-in in size. Under the LCR, samples are collected from five customer taps every year. Vintage on the Ponds also collected water samples periodically for nitrate and monthly for bacterial analysis.

4.2 Treatment Process Description

The treatment process at Vintage on the Ponds included prechlorination/oxidation, detention, and Macrolite® pressure filtration. Macrolite® is a spherical, low-density, ceramic media manufactured by Kinetico for filtration rates at least two times higher than those of conventional gravity filters. The media is approved for use in drinking water applications under NSF International (NSF) Standard 61. The physical properties of the media are summarized in Table 4-2. The vendor considers Macrolite® chemically inert and compatible with chemicals such as oxidants and ferric chloride.

Table 4-2. Physical Properties of 40/60 Mesh Macrolite® Media

Property	Value
Color	Taupe, brown to grey
Thermal Stability (ºC)	1,100
Sphere Size (U.S. standard mesh)	40 × 60
Sphere Size Range (mm)	0.35–0.25
Sphere Size Range (in)	0.0165–0.0098
Uniformity Coefficient	1.2
Bulk Density (g/cm^3)	0.86
Bulk Density (lb/ft^3)	54
Particle Density (g/cm^3)	2.05
Particle Density (lb/ft^3)	129

Source: Kinetico

Figure 4-4 is a schematic of the Macrolite® PM2162D6 pressure filtration system. The system consisted of four preexisting pressure tanks, one HOCl feed system, one contact tank, two pressure filtration vessels (configured in parallel), two preexisting softener units, and associated instrumentation for pressure and flowrate.

Because the filtration system was placed after the four pressure tanks, it operated at variable flowrates based on instantaneous demand from the distribution system. Backwash of the Macrolite® system was triggered by an 18,000-gal throughput setting for each vessel. All plumbing for the system was Schedule 80 polyvinyl chloride (PVC) and the skid-mounted unit was pre-plumbed with the necessary isolation valves, check valves, sampling ports, and other features. Table 4-3 summarizes the design features of the system. The major process steps and system components are presented as follows:

- **Intake –** Raw water was pumped from Well No. 1 at approximately 45 gpm into a series of four 120-gal Well-X-Trol pressure tanks (Model No. WX-350), which controlled the well pump on/off with pressure settings at 40/60 psi and served as temporary water storage. Each pressure tank was individually connected to a 2-in copper header pipe. Upon a call from the distribution system, the pressure tanks supplied raw water to the Macrolite® filtration system and the downstream softener. After the pressure tanks were gradually emptied and the tank pressure was reduced to 40 psi, the well pump was turned on to refill the tanks and supply the water demand. The well pump was turned off as the tank pressure reached the high pressure setting of 60 psi.

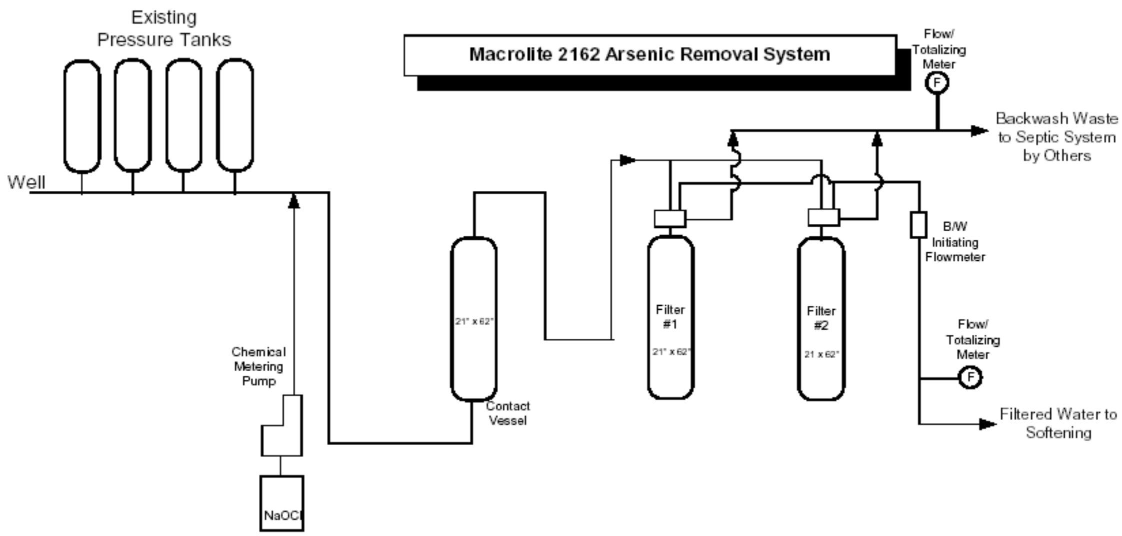

Figure 4-4. Process Schematic of Macrolite® Pressure Filtration System

Table 4-3. Design Specifications for Macrolite® PM2162D6 Pressure Filtration System

Parameter	Value	Remarks
Pretreatment		
Target Prechlorination Dosage (mg/L as Cl_2)	3.0	1 mg/L of chlorine demand estimated for As(III), Fe(II), and Mn(II); Total chlorine residuals of 1.0 mg/L (as Cl_2) targeted after pressure filters to protect cationic ion exchange resin in softeners
Detention		
Tank Quantity	1	–
Tank Size (in)	21 D × 62 H	–
Tank Volume (gal)	82.4	–
Contact Time (min)	1.8	Actual contact time based on on-demand flowrates
Filtration		
Vessel Quantity	2	Parallel configuration
Vessel Size (in)	21 D × 62 H	–
Vessel Cross-Sectional Area (ft^2/vessel)	2.4	–
Media Volume (ft^3/vessel)	4.8	24-in bed depth in each vessel
Peak Flowrate (gpm)	45	Actual flowrate based on on-demand flowrates
Filtration Rate (gpm/ft^2)	9.4	Actual filtration rates based on on-demand flowrates
Δp across vessel (psi)	15	Across a clean bed
Maximum Daily Production (gpd)	64,800	Based on 45 gpm operating at 24 hr/day
Hydraulic Utilization (%)	36	Estimated based on peak daily demand of 23,500 gal
Backwash		
Frequency (gal/vessel)	18,000	Throughput between two consecutive backwash cycles
Backwash Flowrate (gpm/ft^2)	25	
Backwash Duration (min)	12	–
Service-to-Waste Duration (min)	4	15 gpm flowrate
Wastewater Production (gal/vessel)	360	Including 60 gal/vessel from service-to-waste rinse

- **Prechlorination/Oxidation** – NaClO was injected into a 2-in PVC "tee" to oxidize As(III) and Fe(II) before entering the contact tank. The chemical feed system consisted of a 15-gal polyethylene day tank with secondary containment and a Pulsatron Plus Series E Model LPA2 flow-paced metering pump with a maximum capacity of 6 gpd (or 0.9 L/hr). The metering pump was adjusted automatically based on the pulse signals received from a Multi-jet Cold Water flow meter located between the contact tank and the filtration vessels. A 5.25% NaClO solution was originally used from the system startup on July 12, but was switched to a 12.5% NaClO solution on October 26, 2005 to increase the chlorine dosage. The operation of the NaClO feed system was monitored daily by measuring chlorine residuals and chlorine consumption in the day tank. Figure 4-5 is a composite of photographs of the chlorine feed system and its components.

  The target chlorine residual after the pressure filters was 1 mg/L of total chlorine (as Cl_2) to minimize any adverse effect on the resin in the softener units. According to WDNRS' permit approval letter dated June 10, 2005, the chlorine residual through the softening system was limited to 1 mg/L of free chlorine (as Cl_2). However, free chlorine was not expected to be present due to the high ammonia level in source water. Upon further consultation with the resin manufacturer, combined chlorine also would have, perhaps to a lesser extent, adverse impacts on the resin.

Figure 4-5. Chlorine Addition System
(Clockwise from top*: Chlorine Injection Point; Chemical Day Tank and Secondary Containment; Flow-paced Chemical Metering Pump; Chlorine Addition System*)

- **Detention** – One 21-in × 62-in fiberglass reinforced plastic (FRP) tank (see Figure 4-6) was designed to provide 1.8 min of contact time at the peak flowrate of 45 gpm. The actual contact time varied based on the instantaneous water demand from the distribution system. The on-demand flowrates observed were much lower than the peak flowrate during the performance evaluation. The detention was designed to aid in the formation of iron flocs prior to filtration.

Figure 4-6. Contact Tank

- **Pressure Filtration** – The Macrolite® filtration system involved downflow filtration through two pressure filters arranged in parallel (see Figure 4-7). Mounted on a polyurethane-coated steel frame, the filtration system consisted of two 21-in × 62-in FRP pressure vessels, each equipped with an upper 0.5-in slotted plastic diffuser, a lower 0.01-in slotted polyethylene hub and lateral, and 6-in top and bottom flanges. Each vessel was filled with approximately 24 in (4.8 ft^3) of 40/60 mesh Macrolite® media, supported by 6 in of 30/40 mesh garnet underbedding. The standard operation had both vessels on-line with each vessel treating a maximum of 22.5 gpm for a hydraulic loading rate of 9.4 gpm/ft^2. However, because the system was operated "on-demand", the actual flowrate through the system varied based on water demand.

- **Backwash Operations** – Backwash was a fully automated process pre-set on the backwash timer assembly for a throughput of 18,000 gal (through each vessel) determined by a flow totalizer installed on the treated water line (see Figure 4-7). The spent filtration vessel was backwashed with water from the contact tank and the resulting wastewater sent to a septic system. The backwash duration for each vessel was 16 min from start to finish, including 12 min of backwash at 25 gpm and 4 min of service-to-waste rinse at 15 gpm, producing

Figure 4-7. Macrolite® Pressure Filtration System
(Clockwise from Left: Pressure Filters; Backwash Timer Assembly; Totalizer on Treated Waterline)

approximately 360 gal of wastewater per vessel. Both backwash wastewater and filter-to-waste rinse water were discharged to a nearby sanitary sewer line for disposal. Figure 4-8 shows the backwash flow paths for both Vessels A and B, which were backwashed on an alternating basis, i.e., one vessel was backwashed while the other continued to provide treated water to the distribution system. The backwash cycles were repeated as shown in Steps 4 through 6 during system operation. Therefore, the filtration vessels, if viewed as one unit, always had a filtration capacity between 25% (immediately after backwash of one vessel at Step 4) and 75% (immediately before backwash of the other vessel at Step 5).

- **Softening** – Downstream from the pressure filters, the treated water was routed to an Addie Model No. 29TDM-300 water softening system composed of two 24-in-diameter by 48-in-tall softener vessels and one 1,200-lb salt capacity brine tank (Figure 4-3). The water softening system operated with one vessel while the other vessel was in standby mode. Section 4.1 provides additional details of the softening process.

4.3 System Installation

This section summarizes system/building installation activities, including permitting, building preparation, and system offloading, installation, shakedown, and startup.

4.3.1 Permitting. The engineering plans, prepared by Kinetico, included diagrams and specifications for the Macrolite® PM2162D6 arsenic removal system, as well as drawings detailing the connections to the preexisting facility infrastructure. The engineering plans were certified by a

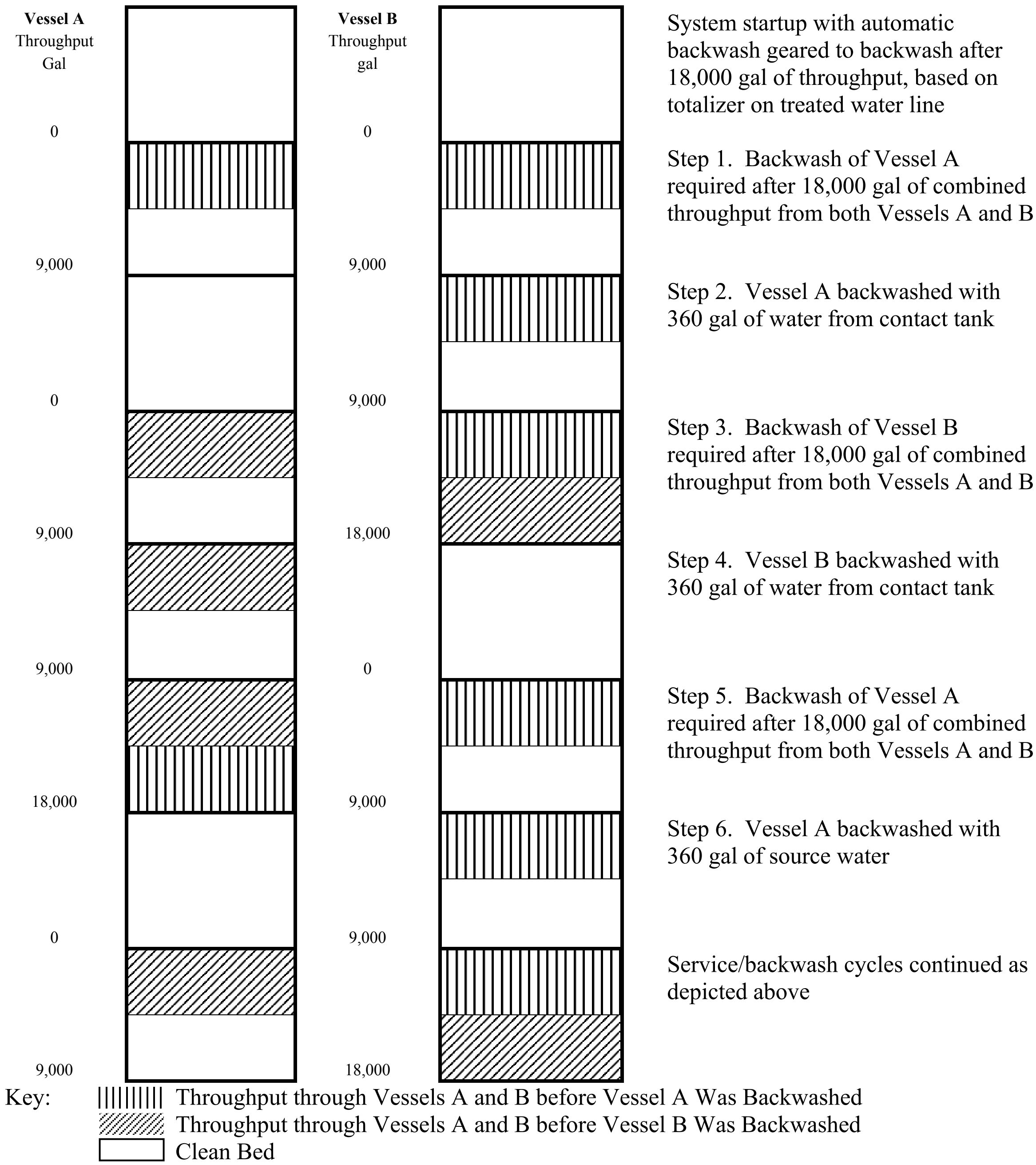

Figure 4-8. Backwash Flow Paths for Both Vessels A and B and a Throughput of 18,000 gal Between Backwash Cycles

Professional Engineer registered in the State of Ohio and submitted to WDNR on April 25, 2005. WDNR's preliminary review comments, received on April 29, 2005, requested a summary table of all design parameters and a chemical feeder submittal checklist. In addition, WDNR requested the facility to provide the design information for the existing softener system and a reporting schedule for the analytical and operational data collected during the one year demonstration project. After incorporating responses to comments, the engineering plans were resubmitted to WDNR on May 24, 2005. WDNR granted the system permit on June 10, 2005 with, among others, two approval conditions related to system installation:

- The discharge piping for the spent brine from the softener units and the backwash wastewater from the Macrolite® filters should have a "2D" (two times the diameter of the discharge piping) air gap. A vacuum breaker tee was actually installed instead of the "2D" air gap, which also prevents a sewer backup from entering the water system (Figure 4-9).
- The 15-gal NaClO chemical day tank should be graduated using a maximum of 0.5 gal increments (Figure 4-9).

In addition, WDNR verbally requested during its startup inspection site visit that the NaClO feed pump be remounted above the solution level to avoid any siphoning of the chemical (Figure 4-9).

On August 29, 2005, WDNR granted approval to relocate the NaClO injection point and the contact flow meter from before to after the four pressure tanks. The request was made because prolonged contact with over 1 mg/L (as Cl_2) of total chlorine potentially could damage butyl rubber in the pressure tanks. Further, WDNR granted approval on October 21, 2005 to the use of a 12.5% NaClO solution to replace the previously approved 5.25% solution in order to meet the higher chlorine demand due to the presence of about 3.0 mg/L of NH_3 (as N) in raw water.

Figure 4-9. Photographs of System Components
(Clockwise from Top: Vacuum Breaker Tee; Chlorine Day Tank with Required Graduation; Pump Relocated from below to above Chlorine Tank Level; Chlorine Injection before Pressure Tanks; Chlorine Injection Point Relocated to after Pressure Tanks; Flow Meter on Treated Water Line)

4.3.2 Building Construction. The existing basement had an adequate footprint to house the arsenic removal system and did not require any modifications before system installation.

4.3.3 System Installation, Shakedown, and Startup. The Macrolite® system was installed by a vendor subcontractor, LTM Water Treatment, beginning on June 17, 2005. The installation activities, which lasted about two weeks, included offloading the arsenic removal system (Figure 4-10), connecting system piping at the tie-in points (including the tie-ins from the discharge piping with the required vacuum breaker tee), completing electrical wiring and connections, and assembling the chlorine addition system. System installation was completed by July 1, 2005.

Figure 4-10. Equipment Off-loading

Upon completion of system installation, the pressure filtration vessels were tested hydraulically before media loading. The Macrolite® filtration media was then backwashed thoroughly to remove media fines and the contact tank and filtration vessels were disinfected according to the applicable American Water Works Association (AWWA) procedures. The chemical feed pump was fine tuned for a target total chlorine residual of 0.5 mg/L (as Cl_2) after the filtration vessels. A water sample was collected for bacteria analysis on July 5, 2006, and the system was bypassed until the result for the bacteria analysis was received on July 7, 2006, and faxed to WDNR the same day.

Two Battelle staff members arrived at the site on July 12, 2005, to inspect the system and conduct operator training for system sampling and data collection. Upon completion of the operator training, a set of samples was collected across the treatment train by the operator with the assistance of Battelle staff members. Under Battelle staff guidance, the operator performed arsenic speciation and onsite measurements for pH, temperature, DO, and ORP using a handheld field meter (see Section 3.5). After careful inspections of the system, a punch list was developed and summarized as follows:

- Remount the chlorine feed pump to above the chlorine tank level to avoid potential siphoning of the chemical (Figure 4-9)
- Install a backwash sample tap
- Install an hour meter
- Install a flow meter on the treated water line and backwash line (Figure 4-9 shows the flow meter on the treated water line)
- Relocate the chlorine injection point and the contact flow meter to after the four pressure tanks to avoid using the pressure tanks as settling tanks and prevent butyl rubber in the pressure tanks from being damaged by chlorine. In addition, moving the chlorine injection

point increase the distance between source water sample tap (denoted as "IN" in Table 3-3) and the chlorine injection point to over 10 ft to avoid any cross contamination (Figure 4-9).

On August 19, 2005, a vendor subcontractor remounted the chlorine feed pump, installed a backwash sample tap, and increased the setting of the chlorine feed pump to achieve the target chlorine residual. On September 14 and then from September 19 to 20, 2005, one Insite® PX-50 GPM-12-V-F flow meter (Figure 4-11) was installed each on the treated water line and the backwash line. On September 22, 2005, the chlorine injection point and the contact flow meter were relocated from before to after the pressure tanks. All action items were completed after the vendor had installed the hour meter in the pump house during the subcontractor's October 25, 2005 site visit.

Figure 4-11. Close-up View of Insite® PX-50 GPM-12-V-F Flow Meter

4.4 System Operation

4.4.1 Operational Parameters. Table 4-4 summarizes the operational parameters for the 14-months of system operation, including operational time, throughput, flowrate, and pressure. Detailed daily operational information also is provided in Appendix A.

Between July 12, 2005, and September 3, 2006, the well operated for approximately 1,072 hr with an average daily operating time of 2.6 hr. Because of lack of an hour meter from startup to October 25, 2005, the well operating time for this period was estimated based on the total throughput through the raw water line and a well pump flowrate of 40 gpm (the average of three values measured by the totalizer on the raw water line and a stopwatch). Although installed on October 25, 2005, hour meter readings were not taken until July 11, 2006. Since then, the readings were recorded only on a quarterly basis. Readings of the hour meter and the totalizer to the treatment system confirmed that the well pump flowrate was indeed 40 gpm, therefore, this value was used to calculate the daily well operating time even after the hour meter had been installed.

During the 14-months of system operation, the system treated approximately 2,500,200 gal of water. The average daily demand was 5,981 gal/day, compared to 6,400 gal/day estimated by the facility operator prior to the demonstration study. The peak daily demand occurred on August 10, 2006, at 19,100 gal, compared to 23,500 gpd provided by the facility. Due to the on-demand system configuration, the total and daily system operating times were not tracked. The on-demand flowrates through the system varied

Table 4-4. System Operation from July 12, 2005 to September 3, 2006

Parameter	Values
Well Pump (Well No. 1)	
Total Operating Time (hr)	1,072
Average Daily Operating Time (hr)	2.6
Average Flowrate (gpm)	40
System Throughput/Demand	
Throughput to Distribution (gal)	2,500,200[a]
Average Daily Demand (gpd)	5,981
Peak Daily Demand (gpd)	19,100[a]
Total Operating Time (hr)	System on demand
Average Daily Operating Time (hr)	System on demand
System – Service Mode	
Flowrate (gpm)	20 (max.)
Contact Times (min)	4.1 (min.)
Hydraulic Loading Rates to Filters (gpm/ft^2)	4.2 (max.)
Range (Average) of System Inlet Pressure[b] (psi)	42 to 60 (51)
Range (Average) of System Outlet Pressure (psi)	10 to 40 (24)
Range (Average) of Δp across Filtration Vessels (psi)	5 to 30 (19)[c]
Range (Average) of Δp across System (psi)	19 to 42 (27)
System – Backwash Mode	
Number of Backwash Cycles (time)	102[d, f]

(a) Based on totalizer on treated water line.
(b) Based on readings from pressure gauge installed on four pressure tanks.
(c) Excluding two readings at 1 and 33 psi.
(d) Excluding manual backwash cycles for sampling purposes and abnormal multiple backwash events taking place daily on September 30, November 29, 2005, May 3, and July 11, 2006.

and were tracked by an Insite® PX-50 GPM-12-V-F flow meter installed on the treated water line. Because the flow meter installed had 2.5-gpm increments up to 50 gpm, accurate flowrate data were not attainable especially over the lower end of the applicable range. Nonetheless, examination of all flowrate data revealed that the maximum flowrate recorded throughout the study period was approximately 20 gpm. Using this value as a basis, the minimum contact time in the contact tank was 4.1 min (compared to the design value of 1.8 min) and the maximum hydraulic loading rate to the Macrolite® filters was 4.2 gpm/ft^2 (compared to the design value of 9.4 gpm/ft^2).

At flowrates of less than 20 gpm, system inlet pressure readings to the system ranged from 42 to 60 psi, which, as expected, were within the operating range of 40 to 60 psi for the pressure tanks. System outlet pressure readings to the downstream softener units ranged from 10 to 40 psi. Differential pressure (Δp) readings across Vessels A and B ranged from 5 to 30 psi (excluding two readings at 1 and 33 psi). As shown in Figure 4-12, Δp readings across Vessels A and B rose gradually from 5–9 psi immediately after system startup and were stabilized at about 15–25 psi approximately one month into system operation. Because the Δp readings were recorded at different stages of various service cycles, the spikes shown in the figure most likely represent the times when the filters were about to be backwashed. Δp readings across the system ranged from 19 to 42 psi.

During the study period, 102 backwash cycles took place. The throughput between two consecutive backwash cycles should have been constant at 18,000 gal; however, some variations were observed throughout. Depending on the daily water usage, the backwash frequency varied from daily to once every several days.

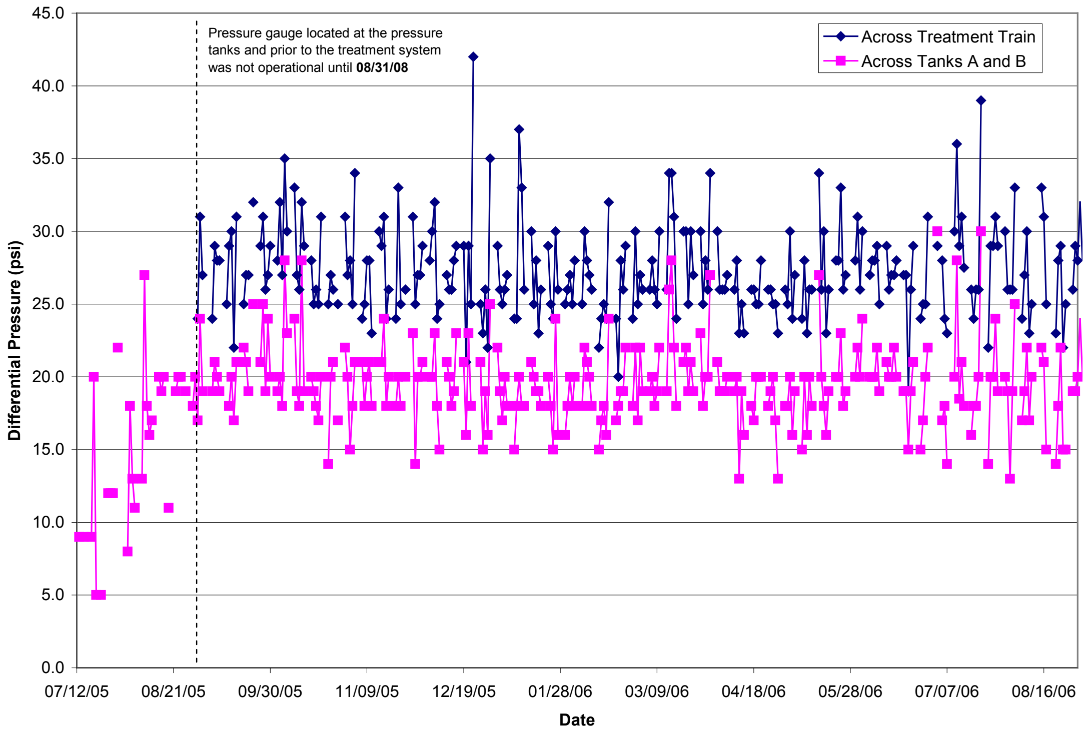

Figure 4-12. Δp Across Vessels A and B and Entire System

4.4.2 Chlorine Addition. As described in Section 4.2., chlorine was added to oxidize Fe(II) and As(III) prior to filtration. Due to the presence of 2.9 mg/L of ammonia, total chlorine residuals measured in the water comprised of primarily mono and dichloramines with little or no free chlorine (since breakpoint chlorination was not performed). As such only total chlorine residual data are discussed herein. Figure 4-13 presents total chlorine residuals measured after the contact tank (AC) and in the plant effluent (TT). The erratic chlorine residual values shown in the figure reflect the many operational difficulties experienced with the chlorine injection system. The problems encountered and corrective actions taken are summarized in Table 4-5 and discussed below.

For the first three months of system operation through October 2005, except for a few occasions, little or no chlorine residuals were measured after the contact tank and in the system effluent. Failures to detect chlorine residuals were attributed to factors such as problems with the chlorine test kit, chlorine feed pump, and chlorine injector, and insufficient chlorine dosage with the use of a 5.25% NaClO solution. Initial attempts to correct the problems included replacing a potentially malfunctioning N,N diethyl-p-phenylene diamine (DPD) reagent dispenser with DPD pillows for chlorine residual measurements and increasing the chlorine injection rate by stepping up the stroke length of the chlorine feed pump from 70 to 83.5%. Since August 23, 2005, the operator noticed no change in the chlorine tank level, indicating no chlorine addition. A broken compression fitting on the chlorine feed pump was later identified as the root cause and replaced on September 19–20, 2005. Two days later, the chlorine injection point was relocated from before to after the pressure tanks to prevent the butyl rubber diaphragms in the pressure tanks from being damaged. After relocation, the chlorine injector did not bleed properly and had to be repaired by the vendor's subcontractor a week later.

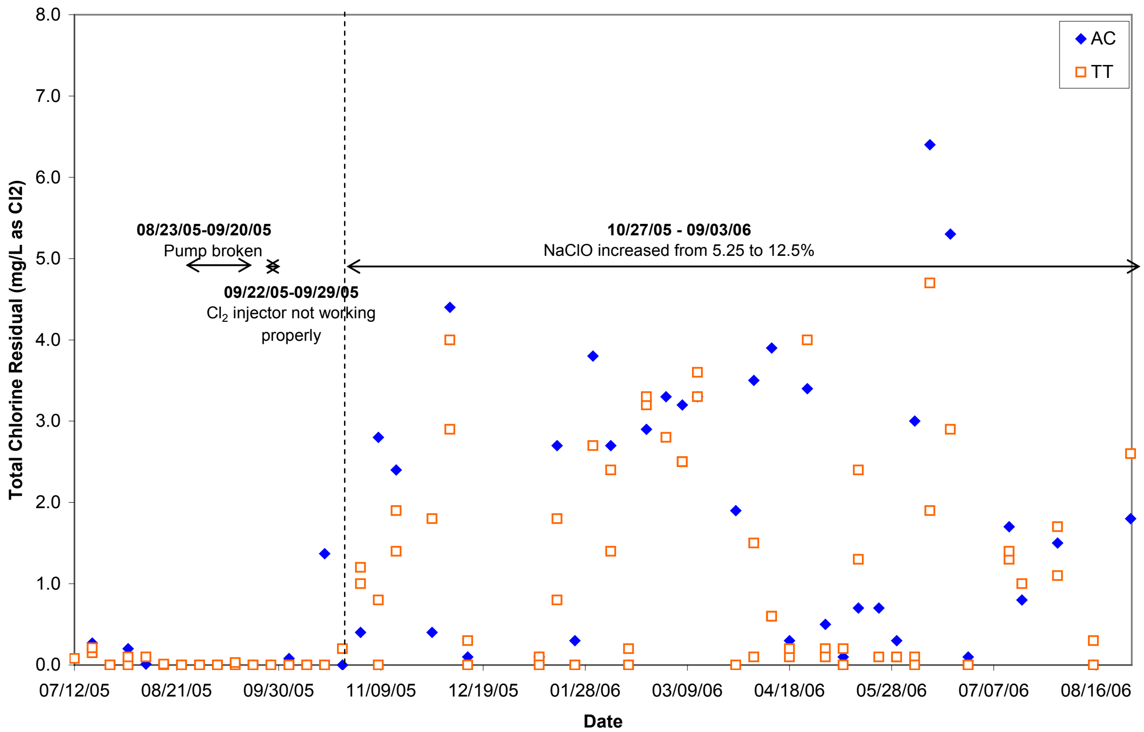

Figure 4-13. Total Chlorine Residuals at AC and TT Locations

After switching to a 12.5% NaClO solution on October 27, 2005, both chlorine dosages and chlorine residuals were increased significantly, as shown in Figure 4-13. The actual chlorine dosages based on chlorine tank level measurements ranged from 1.3 to 5.9 mg/L (as Cl_2). With approximately 1 mg/L (as Cl_2) of chlorine demand for Fe(II), Mn(II), and As(III) and an unknown amount for the organic matter in raw water, total chlorine residuals in the treated water should have been no more than 0.3 to 4.9 mg/L (as Cl_2), a range that covered the majority of the measured residual data points as shown in Figure 4-13. It is suspected that the measured total chlorine residual data might be somewhat higher than the actual concentrations due to the inadvertent use of high range (HR) test kits designed for a higher concentration range (i.e., from 0.1 to 8.0 mg/L [as Cl_2]). During a site visit in July 2006, a Battelle staff member measured a set of samples using both the high and low range (designed for 0.02 to 2.0 mg/L [as Cl_2]) test kits and obtained 0.2–0.3 and 0.4–1.4 mg/L (as Cl_2) of total chlorine residuals, respectively. Therefore, the use of HR test kits could have skewed the test results to some extent.

Leaks were developed after switching from 5.25 to 12.5 % NaClO solution due to incompatibility of the plumbing material with the stronger NaClO solution. A leak was first discovered between the ½-in copper chlorine injector and 2-in copper "tee" on November 4, 2005. After being patched, the leak continued at the 2-in copper "tee". The ½-in copper chlorine injector and 2-in copper "tee" were then replaced with the equivalent PVC parts on November 7, 2005. A leak was discovered again on the 2-in PVC "tee" on November 11, 2005, caused by a cracked plastic fitting, and was fixed on the same day. Since then, no more repairs have been performed on the chlorine addition system, except for the pump's (losing prime) periodically due to airlocks, causing little or no consumption of the chlorine solution.

Table 4-5. Summary of Problems Encountered and Corrective Actions Taken for Chlorine Injection System

Duration	Problem(s) Encountered	Corrective Action(s) Taken	Work Performed by/on
07/12/05–08/23/05	Little or no chlorine residuals measured	• Examined Hach test kit and switched from DPD reagent dispenser to DPD reagent powder pillows since 07/19/05 • Remounted pump and increased pump stroke length from 70 to 83.5% on 08/19/05	• Operator • Vendor's subcontractor on 08/19/05
08/23/05–09/20/05	No change in chlorine tank level and no chlorine residuals measured	• Replaced broken compression fitting on pump	• Vendor's subcontractor on 09/19–20/05
07/12/05–09/22/05	Chlorine injection point installed before pressure tanks	• Relocated ½-in copper injection point from before to after pressure tanks	• Vendor's subcontractor on 09/22/05
09/22/05–09/29/05	No chlorine residuals measured	• Fixed chlorine injector that did not bleed properly after its relocation on 09/22/05 • Adjusted pump stroke length to 62%	• Vendor's subcontractor on 09/29/05
09/29/05–10/27/05	No chlorine residuals measured	• Adjusted pump stroke length to 74%, then 76% • Cleaned pump injection fitting • Replaced chlorine stock solution from 5.25 to 12.5%	• Operator and vendor's subcontractor on 10/11/05 • Vendor's subcontractor on 10/18–19/05 followed by vendor technician on 10/25–27/05
11/04/05	Leaks between ½-in copper chlorine injector and 2-in copper pipe	• Patched leaks between ½-in copper chlorine injector and 2-in copper pipe	• Vendor's subcontractor on 11/04/05
11/07/05	Leaks between ½-in copper chlorine injector and 2-in copper pipe	• Replaced ½-in copper chlorine injector and 2-in copper "tee" with equivalent PVC injector and "tee"	• Vendor's subcontractor on 11/07/05
11/11/05	Leaks on 2-in PVC pipe observed	• Replaced a cracked PVC fitting on 2-in PVC "tee" installed on 11/07/05	• Vendor's subcontractor on 11/11/05

To limit the total chlorine residual to not exceed 1 mg/L (as Cl_2) before entering the downstream softener, constant adjustments had to be made to the pump stroke length (see Table 4-6). However, the resulting chlorine dosage based on the day tank measurements did not appear to respond to the stroke length adjustment. For example, when the stroke length was reduced from 80 to 68%, the chlorine dosage, in effect, increased from 3.4 to 3.6 mg/L. (Note that the dosages based on the pump rated capacity at 80 and 68% stroke lengths were 3.2 and 2.7 mg/L [as Cl_2], respectively.) The reasons that might have contributed to such discrepancies include: (1) difficulties to accurately measure the chlorine dosages by reading tank levels with 0.5-gal graduations, (2) leaks, airlocks, and varying injection rates by the paced pump that affected the amount of chlorine metered into the water, and (3) improper calibration of the metering pump so the flow sensor might not have generated correct pulse signals at varying flowrates and the pulse signals might not have properly converted to the pump speed.

Table 4-6. Correlations Between Pump Stroke Length and Cl_2 Dosage

Duration	Stroke Length (%)	Average Cl_2 Dosage (μg/L)
07/12/05 to 08/18/05	70	1.4
08/19/05 to 09/28/05	83.5	NA
09/29/05 to 10/10/05	62	0.5
10/11/05 to 10/26/05	74	0.7
10/27/05 to 11/03/05	82	2.3
11/04/05 to 11/20/05	80	3.5
11/21/05 to 11/28/05	78	2.1
11/29/05 to 12/04/05	75	2.4
12/05/05 to 12/06/05	72	4.1
12/07/05 to 12/13/05	65	3.4
12/14/05 to 01/26/05	68	3.6
01/27/06 to 02/12/06	66	1.5
02/23/06 to 03/19/06	68	3.2
03/20/06 to 03/23/06	66	1.7
03/24/06 to 09/03/06	62	2.4

4.4.3 Residual Management. Residuals produced by the operation of the Macrolite® system consisted of only backwash wastewater, which was discharged to a nearby sanitary sewer line. Backwash frequency and quantities of backwash wastewater generated are discussed in Section 4.4.1.

4.4.4 System/Operation Reliability and Simplicity. During the 14 months of system operation, a total of nine visits were made by the vendor and/or its subcontractor to fix the chlorine addition system and leaks at the chlorine injection point as described in Section 4.4.2. There was no unscheduled system downtime, but the system was allowed to operate without the use of chlorine for 63 days from August 23 through September 20, 2005, and from September 22 through October 27, 2005. In addition, another visit was made by the subcontractor to replace the piston located in the control valve near the top of Vessel A. The broken piston prevented the vessels from being backwashed from April 20 to May 3, 2006, leading to particulate breakthrough.

Pre- and Post-Treatment Requirements. The only pretreatment required was prechlorination for the oxidation of arsenic and iron. However, as noted in Section 4.4.2, issues related to the chemical feed pump prevented chlorine from being added to the water before October 27, 2005. Specific chemical handling requirements are further discussed below under chemical handling and inventory requirements. The post-treatment included preexisting softening.

System Automation. All major functions of the treatment system were automated and required only minimal operator oversight and intervention if all functions were operating as intended. Automated processes included turning on and off the well pump based on the low and high pressure settings of the pressure tanks, feeding chlorine to raw water using a paced-chemical feed pump according to the demand in the distribution system, and initiating filter backwash and fast rinse based on a preset throughput value. The flow-paced chemical feed pump, although automatically triggered by the contact meter, had to be frequently monitored for airlocks after it was repaired on October 27, 2005. Air bubbles in the pump head were discharged through an air bleed valve and a return line to the chemical day tank. No other issues arose with the automated backwash and associated equipment throughout the performance evaluation.

Operator Skill Requirements. Under normal operating conditions, the skills required to operate the Macrolite® pressure filtration system included maintaining proper operation of the process equipment; observing and recording associated operating parameters, such as pressure, flow, and chlorine residuals; keeping track of the NaClO solution consumption and replenishing the chemical day tank, when necessary; performing on-site chlorine residual measurements to help meet the target total chlorine residual after the pressure filters; and working with the vendor to troubleshoot and perform minor on-site repairs. Difficulties were encountered when trying to maintain proper operation of the chemical feed pump (as discussed in Section 4.4.2), taking the flow readings due to normally low on-demand flowrates and the oversized flow-meter installed (as discussed in Section 4.3.3), and performing routine on-site chlorine residual measurements. Because the certified operator retained by Vintage of the Ponds was located one and a half hours away from the site, all O&M activities were performed by the nursing home manager (referred to, in this report, as the operator), who had very little prior experience of operating a water treatment system.

According to the plant operator, daily demand on the operator was about 5 min to visually inspect the system and record the operating parameters on the log sheets. Additional time was required for troubleshooting and maintaining proper operation of the chemical feed system.

Operator certifications in Wisconsin consist of one class and five subclasses, i.e., O, Z, I, L, and V, which are classified based on types of treatment (http://dnr.wi.gov/org/es/science/opcert). Subclass O certification is for those who operate general water treatment systems; Subclass Z for zeolite and resin treatment; Subclass I for oxidation and filtration treatment; Subclass L for lime-soda ash treatment; and Subclass V for specialized treatment. The certified operator for Vintage on the Ponds has a Subclass O certificate. Each subclass requires a high school or equivalent diploma, at least two years of experience operating a water system prior to December 1, 2000, and successful completion of application and examination for that specific subclass.

Preventive Maintenance Activities. Preventive maintenance tasks recommended by the vendor included daily to monthly visual inspections of the piping, valves, tanks, flow meters, and other system components. Specific O&M activities performed by the vendor for this reporting period are summarized in Table 4-5.

Chemical/Media Handling and Inventory Requirements. With the assistance of the certified operator, all personal protective equipment, including neoprene rubber gloves, chemical safety goggles, a protective apron, and an emergency shower and eyewash station, was supplied by the facility, satisfying the safety requirements for the NaClO chemical handling as specified in the NaClO Material Safety Data Sheet (MSDS). The operator refilled the chemical day tank with a handheld pump to 15-gal every time the volume was down to 10-gal, which occurred approximately once every four weeks. Refilling the chlorine took about 10 min to complete. The chemical consumption in the day tank, along with total chlorine residuals in the filter effluent at the TT sampling location, were checked daily as part of the routine operational data collection as required by WDNR.

4.5 System Performance

The performance of the Macrolite® PM2162D6 Arsenic Removal System was evaluated based on analyses of water samples collected from the treatment plant, backwash lines, and distribution system.

4.5.1 Treatment Plant Sampling. Water samples were collected at five locations (i.e., IN, AC, TA, TB, and TT) across the treatment train. Table 4-7 summarizes the arsenic, iron, and manganese analytical results. Table 4-8 summarizes the results of the other water quality parameters. Appendix B

Table 4-7. Summary of Arsenic, Iron, and Manganese Analytical Results[(a)]

Parameter	Sampling Location	Unit	Sample Count	Concentration Minimum	Concentration Maximum	Concentration Average	Standard Deviation
As (total)	IN	μg/L	56[(b)]	14.3	29.0	18.9	2.8
	AC	μg/L	48 [9]	15.1 [14.0]	27.6 [20.5]	19.1 [17.3]	2.9 [2.4]
	TA	μg/L	36 [7]	2.3 [8.1]	16.7 [19.9]	5.2 [13.3]	2.7 [5.0]
	TB	μg/L	36 [7]	2.4 [7.8]	7.3 [21.0]	4.5 [13.1]	1.5 [5.5]
	TT	μg/L	12 [2]	2.6 [12.7]	16.5 [16.7]	6.0 [14.7]	3.8 [2.8]
As (soluble)	IN	μg/L	14	15.7	19.6	17.7	1.2
	AC	μg/L	12 [2]	5.6 [12.6]	15.5 [15.1]	9.5 [13.9]	2.8 [1.8]
	TT	μg/L	12 [2]	2.5 [11.6]	7.7 [16.8]	4.9 [14.2]	1.8 [3.7]
As (particulate)	IN	μg/L	14	<0.1	13.3	2.4	3.5
	AC	μg/L	12 [2]	2.6 [3.2]	20.0 [4.9]	10.8 [4.0]	4.5 [1.3]
	TT	μg/L	12 [2]	<0.1 [0.1]	11.3 [1.1]	1.2 [0.6]	3.2 [0.7]
As(III)	IN	μg/L	14	14.0	18.6	16.3	1.3
	AC	μg/L	12 [2]	1.9 [8.0]	9.7 [13.6]	4.6 [10.8]	2.0 [3.9]
	TT	μg/L	12 [2]	1.1 [9.9]	5.9 [15.1]	2.9 [12.5]	2.0 [3.7]
As(V)	IN	μg/L	14	<0.1	3.7	1.4	1.0
	AC	μg/L	12 [2]	2.7 [0.1]	8.5 [7.1]	4.9 [3.6]	1.4 [5.0]
	TT	μg/L	12 [2]	0.5 [1.8]	3.9 [1.8]	1.9 [1.8]	1.0 [-]
Fe (total)	IN	μg/L	56[(b)]	997	2,478	1,392	211
	AC	μg/L	48 [9]	1,072 [1,232]	2,170 [1,602]	1,384 [1,443]	202 [131]
	TA	μg/L	36 [7]	<25 [537]	1,280 [1,499]	158 [1,039]	281 [420]
	TB	μg/L	36 [7]	<25 [448]	397 [1,525]	100 [1,010]	124 [467]
	TT	μg/L	12 [2]	<25 [834]	1,400 [1,596]	235 [1,215]	484 [539]
Fe (soluble)	IN	μg/L	14	996	1,846	1,423	208
	AC	μg/L	12 [1[(c)]]	130 [1,131]	1,120 [1,131]	429 [1,131]	263 [-]
	TT	μg/L	11[(d)] [2]	<25 [832]	157 [1,417]	39 [1,125]	58 [414]
Mn (total)	IN	μg/L	56[(b)]	15.4	36.7	19.2	4.1
	AC	μg/L	48 [9]	15.7 [16.1]	21.2 [19.2]	18.2 [17.8]	1.3 [1.1]
	TA	μg/L	36 [7]	9.5 [15.9]	23.4 [19.5]	17.4 [17.4]	2.4 [1.2]
	TB	μg/L	36 [7]	14.0 [15.9]	23.0 [19.7]	17.7 [17.5]	1.9 [1.3]
	TT	μg/L	12 [2]	15.7 [19.2]	20.4 [21.0]	18.4 [20.1]	1.5 [1.2]
Mn (soluble)	IN	μg/L	14	17.0	32.4	20.1	3.9
	AC	μg/L	12 [2]	16.1 [11.8]	20.8 [18.7]	18.1 [15.2]	1.4 [4.9]
	TT	μg/L	12 [2]	15.6 [20.8]	21.5 [20.8]	18.8 [20.8]	1.8 [-]

(a) Numbers in parentheses representing data compiled from sampling events having problems with chlorine addition system on 08/30/05, 09/06/05, 09/13/05, 09/27/05, 10/04/05, 10/11/05, 10/18/05, and 10/25/05.
(b) 08/30/05 results considered as outliers and not included in calculations.
(c) 09/27/05 result considered as outliers and not included in calculations.
(d) 03/28/06 result considered as outliers and not included in calculations.
One-half of detection limit used for non-detect samples for calculations.
Duplicate samples are included in calculations.

Table 4-8. Summary of Analytical Results of Other Water Quality Parameters

Parameter	Sampling Location	Unit	Number of Samples	Minimum Concentration	Maximum Concentration	Average Concentration	Standard Deviation
Alkalinity (as $CaCO_3$)	IN	mg/L	57	330	384	359	10.3
	AC	mg/L	57	334	378	360	9.6
	TA	mg/L	43	349	374	361	7.9
	TB	mg/L	43	347	392	364	9.9
	TT	mg/L	14	351	390	360	10.6
Ammonia (as N)	IN	mg/L	38[(a)]	2.3	3.9	2.9	0.3
	AC	mg/L	38	0.5	3.7	2.7	0.5
	TA	mg/L	29	0.5	3.5	2.7	0.5
	TB	mg/L	29	0.6	3.6	2.7	0.5
	TT	mg/L	9	2.3	2.9	2.7	0.2
Fluoride	IN	mg/L	17	0.1	0.3	0.2	0.03
	AC	mg/L	17	0.1	0.3	0.2	0.04
	TT	mg/L	20[(b)]	0.1	0.3	0.2	0.03
Sulfate	IN	mg/L	17	<1	<1	<1	-
	AC	mg/L	17	<1	<1	<1	-
	TT	mg/L	20[(b)]	<1	<1	<1	-
Phosphorus (as P)	IN	mg/L	44	<10	91.2	69.6	13.5
	AC	mg/L	44	<10	110	70.4	15.8
	TA	mg/L	33	<10	58.0	<10	11.5
	TB	mg/L	33	<10	58.0	<10	11.1
	TT	mg/L	11	<10	69.1	11.7	19.3
Silica (as SiO_2)	IN	mg/L	57	13.0	16.7	14.5	0.7
	AC	mg/L	57	13.0	16.8	14.5	0.7
	TA	mg/L	43	13.3	16.8	14.5	0.7
	TB	mg/L	43	13.1	16.5	14.4	0.7
	TT	mg/L	14	13.1	16.0	14.3	0.7
Nitrate (as N)	IN	mg/L	17	<0.05	0.11	<0.05	0.02
	AC	mg/L	17	<0.05	0.11	<0.05	0.03
	TT	mg/L	20[(b)]	<0.05	0.24	0.06	0.06
Turbidity	IN	NTU	57	10.0	22.0	16.2	2.7
	AC	NTU	57	1.4	18.0	4.8	4.4
	TA	NTU	42[(c)]	<0.1	20.4	3.8	5.7
	TB	NTU	43	0.1	19.0	3.4	5.4
	TT	NTU	14	<0.1	20.0	4.0	6.6
pH	IN	S.U.	51	7.1	8.1	7.5	0.2
	AC	S.U.	51	7.2	8.1	7.5	0.2
	TA	S.U.	38	7.2	8.1	7.5	0.2
	TB	S.U.	38	7.2	8.1	7.5	0.2
	TT	S.U.	13	7.4	8.0	7.5	0.2
Temperature	IN	°C	51	11.8	16.3	13.9	1.0
	AC	°C	51	10.9	16.0	13.4	1.0
	TA	°C	38	11.6	15.5	13.3	1.0
	TB	°C	38	11.2	15.3	13.2	1.1
	TT	°C	13	12.1	15.4	13.4	1.1

Table 4-8. Summary of Analytical Results of Other Water Quality Parameters (Continued)

Parameter	Sampling Location	Unit	Sample Count	Minimum Concentration	Maximum Concentration	Average Concentration	Standard Deviation
Total Hardness (as $CaCO_3$)	IN	mg/L	14	262	510	322	58.2
	AC	mg/L	14	281	357	311	22.8
	TT	mg/L	14	258	365	311	27.4
Ca Hardness (as $CaCO_3$)	IN	mg/L	14	132	260	172	29.3
	AC	mg/L	14	143	195	167	15.2
	TT	mg/L	14	132	191	166	17.7
Mg Hardness (as $CaCO_3$)	IN	mg/L	14	117	172	144	12.8
	AC	mg/L	14	117	172	144	12.8
	TT	mg/L	14	123	173	145	13.3

(a) 08/15/06 result considered an outlier and not included in calculations.
(b) Including TA and TB locations for samples taken on 07/19/05, 07/26/05, and 08/02/05.
(c) 01/24/06 result considered an outlier and not included in calculations.
One-half of detection limit used for non-detect samples for calculations.
Duplicate samples included in calculations.

contains a complete set of analytical results through the 14-month duration of system operation. The results of the water samples collected throughout the treatment plant are discussed below.

Arsenic and Iron. The key parameter for evaluating the effectiveness of the Macrolite® filtration system was the concentration of total arsenic in the treated water. The treatment plant water was sampled on 57 occasions (including four duplicate sampling events) throughout the study period, with field speciation performed 14 times. Figure 4-14 shows the arsenic speciation results across the treatment train.

Total arsenic concentrations in source water ranged from 14.3 to 29.0 μg/L and averaged 18.9 μg/L (Table 4-7). Soluble As(III) was the predominant species in source water, ranging from 14.0 to 18.6 μg/L and averaging 16.3 μg/L. Only trace amounts of particulate arsenic and soluble As(V) existed, with concentrations averaging 2.4 and 1.4 μg/L, respectively. The arsenic concentrations measured during this 14-month study period were consistent with those in source water sample collected on September 20, 2004 (Table 4-1).

Total iron concentrations in source water ranged from 997 to 2,478 μg/L and averaged 1,392 μg/L, which existed primarily in the soluble form with an average value of 1,422 μg/L (Table 4-7). The soluble iron to soluble arsenic ratio was 80:1 given the average soluble iron and soluble arsenic levels in source water.

As shown in Figure 4-14, for the 14 speciation sampling events, 11 TT samples were below 10 μg/L of arsenic. For the other three events, the two on September 27 and October 25, 2005, had insufficient chlorine addition due to problems with the chlorine addition system, as discussed in Section 4.4.2, and the one on April 25, 2006, had particulate arsenic breakthrough due to failure to backwash at the specified throughput setting caused by malfunctioning of Vessel B, as discussed in Section 4.4.4. Problems with the chlorine addition system resulted in elevated soluble As(III) and iron concentrations in the treated water. For example, total arsenic concentrations at the TT location were 16.6 and 12.7 μg/L, respectively, with most existing as As(III) at 15.1 and 9.9 μg/L, respectively (data shown in parentheses in Table 4-7). The corresponding total iron concentrations were 1,596 and 834 μg/L, with most existing in the soluble form at 1,417 and 832 μg/L, respectively. These elevated results were consistent with the results of five of six other regular sampling events taking place on August 30, September 6 and 13, and October 4, 11, and 18, 2005 (Figures 4-15 and 4-16) when insufficient chlorine was added due to the problems with the

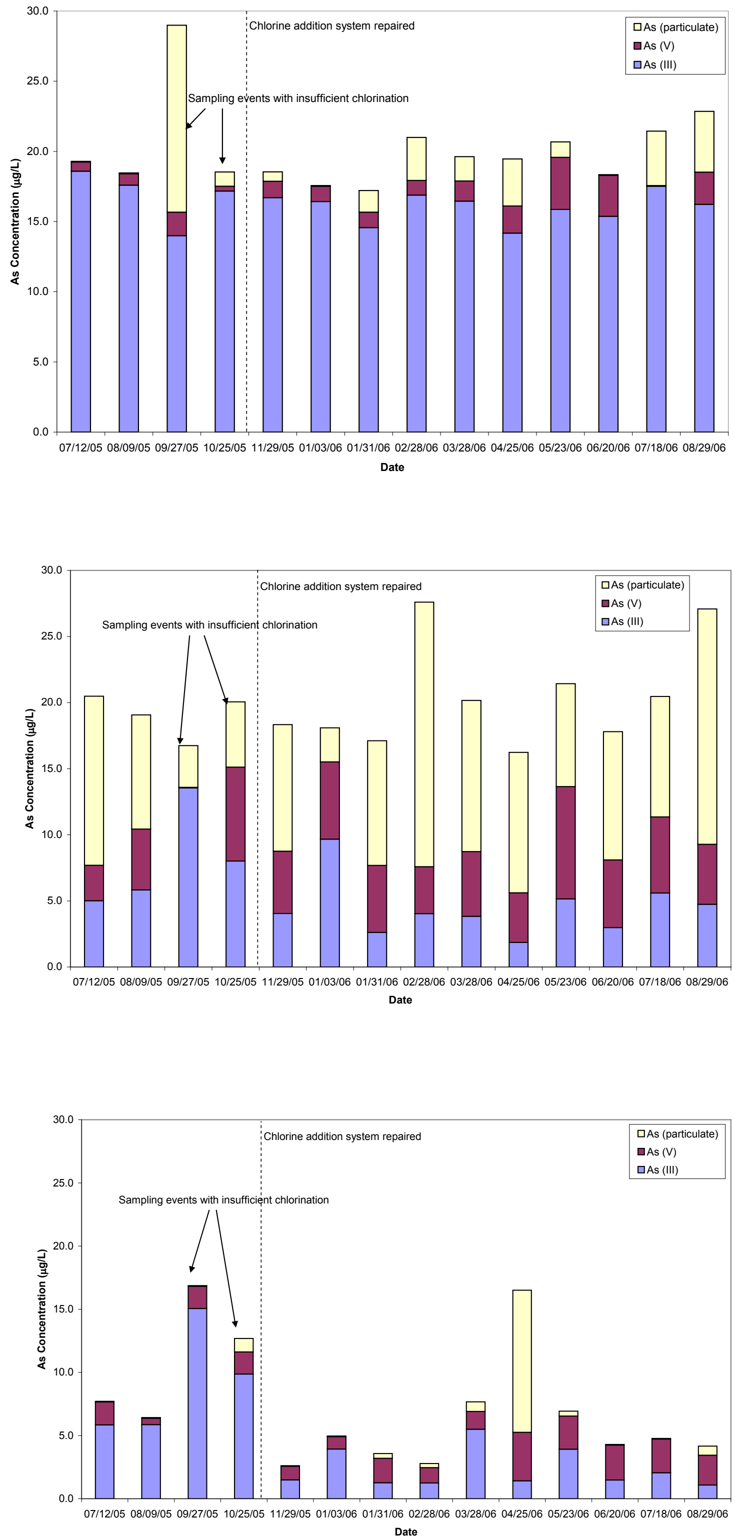

Figure 4-14. Concentrations of Arsenic Species at IN, AC, and TT Sampling Locations

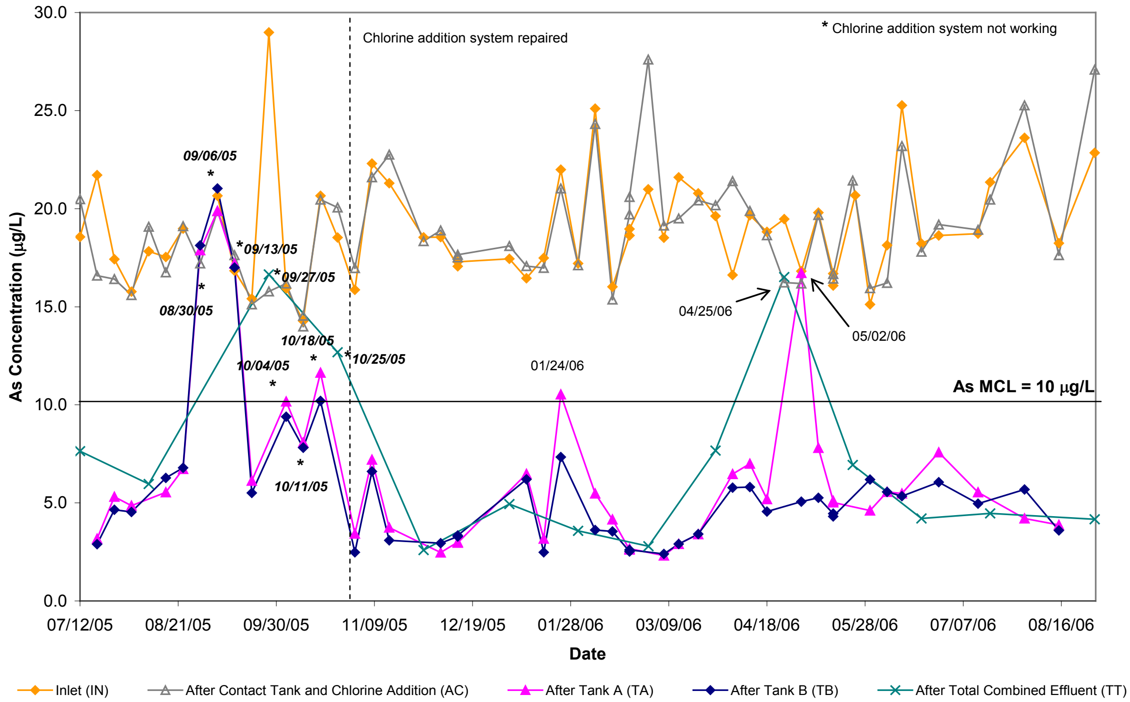

Figure 4-15. Total Arsenic Concentrations at IN, AC, TA, TB, and TT Sampling Locations

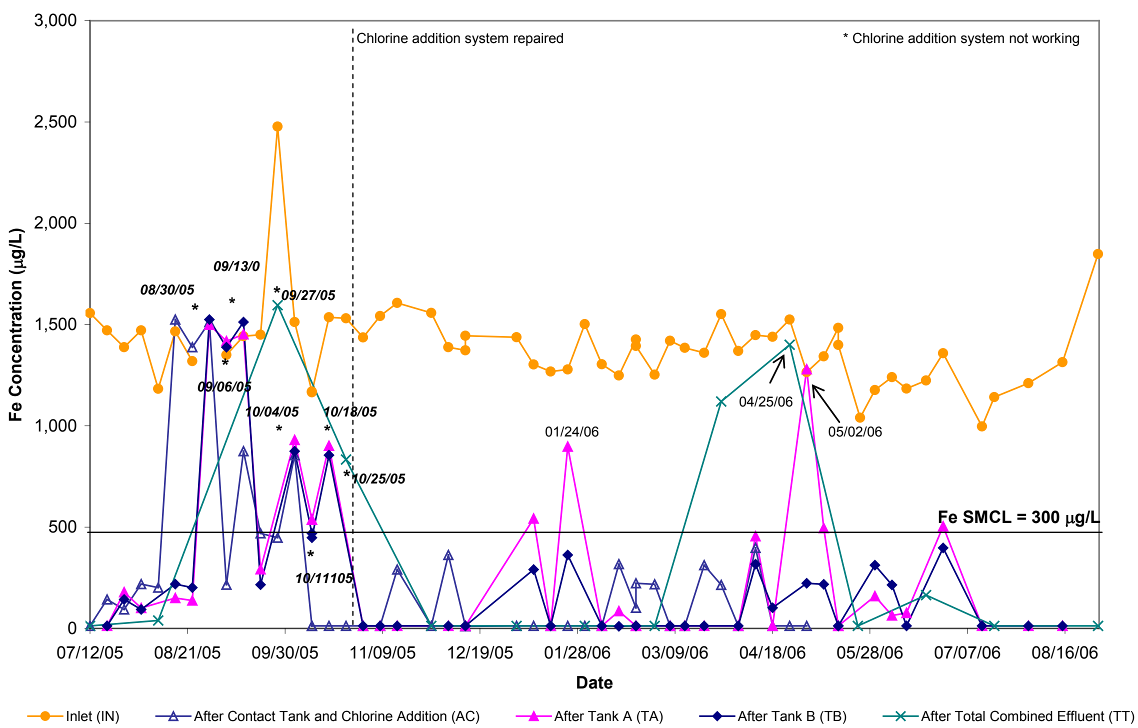

Figure 4-16. Total Iron Concentrations at IN, AC, TA, TB, and TT Sampling Locations

chlorine injection system. For these five events, total arsenic concentrations ranged from 9.4 to 21.0 µg/L and total iron concentrations ranged from 856 to 1,525 µg/L at the TA, TB, and TT sampling locations.

For the 12 speciation sampling events having sufficient chlorine addition (including the one with particulate breakthrough on April 25, 2006), As(III) concentrations were reduced from an average of 16.3 µg/L in raw water to 4.6 µg/L after the contact tank. Correspondingly, particulate arsenic concentrations were increased from an average of 2.4 to 10.8 µg/L. This, along with the moderate increase in As(V) concentration following the contact tank (i.e., from 1.4 to 4.9 µg/L), confirmed that As(V) formed via oxidation of As(III) adsorbed onto and/or co-precipitated with iron solids and formed arsenic-laden particles. As(III) concentrations after the pressure filters averaged 2.9 µg/L, suggesting additional As(III) oxidation through the filters. As(V) concentrations after the filters were further reduced to 1.9 µg/L, suggesting additional As(V) removal via adsorption onto iron solids intercepted by the filters. Particulate arsenic levels after the pressure filters averaged 1.2 µg/L, indicating effective particulate removal by the filters. Note that, in addition to the April 25, 2006 speciation sampling event mentioned above, two other regular sampling events on January 24 and May 2, 2006 (after the chlorine addition system had been fixed), also had higher than 10-µg/L arsenic breakthrough in the filter effluent (Figure 4-15). In each event, a high total iron concentration was measured (Figure 4-16), indicating particulate breakthrough from the filters.

Decreases in As(III) concentration after the contact tank were not as significant as those observed at many other demonstration sites, where As(III) was almost completely converted to either As(V) and particulate arsenic (Condit et al., 2006). Most of these sites had little or no ammonia in raw water, suggesting that presence of ammonia in the Vintage's raw water impacted As(III) oxidation. Ghurye and Clifford (2001) reported that pre-formed monochloramines were ineffective for As(III) oxidation and that limited oxidation could be achieved when monochloramine was formed in situ. The injected chlorine probably reacted with both As(III) and ammonia before being quenched by ammonia to form chloramines.

Incomplete iron oxidation also was observed after the contact tank. For the 12 speciation events where sufficient chlorine was added, as much as 429 µg/L of dissolved iron (on average) was measured after chlorine addition and contact tank. The chlorine added might have reacted with both soluble iron and ammonia before being quenched by ammonia to form chloramines. Soluble iron concentrations were reduced to an average of 39 µg/L after the pressure filters, suggesting more complete oxidation of soluble iron with prolonged contact times (Vikesland and Valentine, 2002). After filtration, total iron concentrations ranged from <25 to 1,400 µg/L (not including data in parentheses in Table 4-7) and averaged 158, 100, and 235 µg/L at the TA, TB, and TT sampling locations, respectively. As discussed above, particulate iron breakthrough was observed in a number instances as evidenced by the spikes shown in Figure 4-16.

Manganese. Total manganese levels in source water ranged from 15.5 to 36.7 µg/L and averaged 19.2 µg/L (Table 4-7), which were below the Secondary Maximum Contaminant Level (SMCL) of 50 µg/L. Manganese in source water existed almost entirely in the soluble form at levels ranging from 17.0 to 32.4 µg/L and averaging 20.1 µg/L. For the two speciation events without sufficient chlorine addition, soluble manganese concentrations after the contact tank ranged from 11.8 to 18.7 µg/L and averaged 15.2 µg/L. For the 12 speciation events with sufficient chlorine addition, soluble manganese concentrations after the contact tank were at similar levels, ranging from 16.1 to 20.8 µg/L and averaging 18.1 µg/L. Chloramines formed during prechlorination apparently were ineffective at oxidizing Mn(II). Manganese after chlorination remained in the soluble form, which was not filtered out by the pressure filters. Soluble manganese in the treated water averaged 20.8 and 18.8 µg/L for the sampling events without and with sufficient chlorine addition (Figure 4-17).

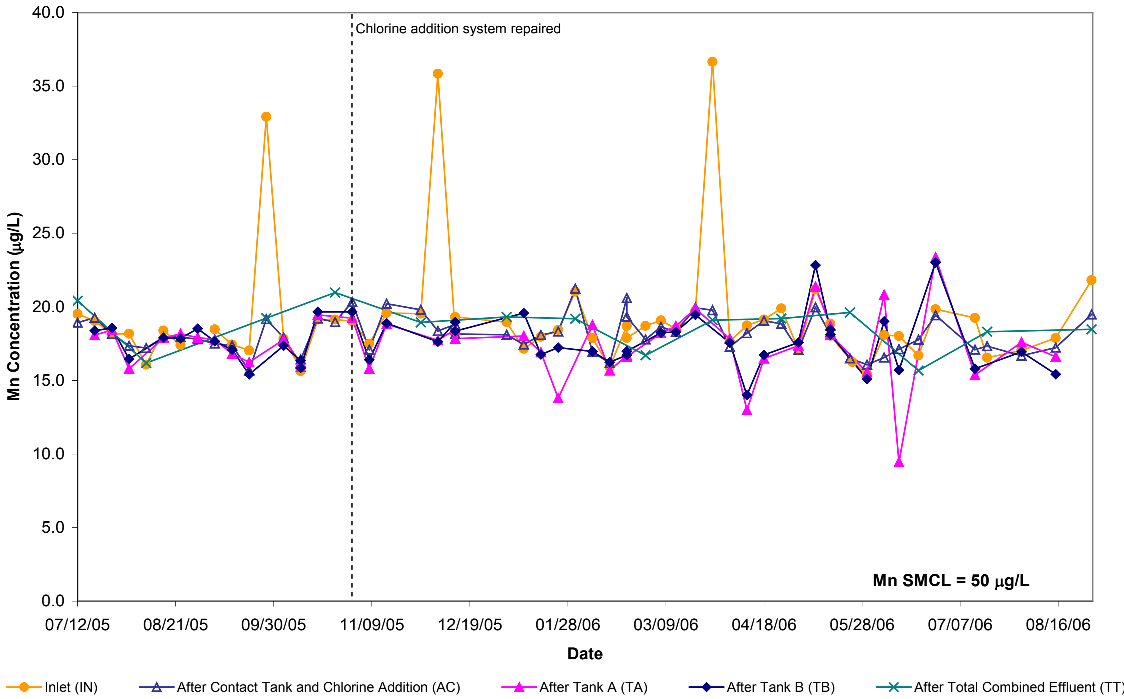

Figure 4-17. Total Manganese Concentrations at IN, AC, TA, TB, and TT Sampling Locations

Other Water Quality Parameters. In addition to the arsenic, iron, and manganese analyses, other water quality parameters were analyzed to provide insight into the chemical processes occurring with the treatment systems. As shown in Table 4-8, ammonia concentrations in source water ranged from 2.3 to 3.9 mg/L (as N) and averaged 2.9 mg/L (as N). Upon chlorination, 0.2 mg/L of ammonia (as N), on average, reacted with chlorine to form combined chlorine, leaving the rest to be removed by the downstream softener units before entering the distribution system.

Average total hardness results ranged from 311 to 322 mg/L (as $CaCO_3$) across the treatment train; total hardness is the sum of calcium hardness and magnesium hardness. The water had an almost equal split between calcium and magnesium hardness. Average fluoride concentrations were 0.2 mg/L in source water and after contact tank and were not affected by the Macrolite® filtration. Average nitrate concentrations ranged from <0.05 to 0.06 mg/L (as N) and phosphorus concentrations ranged from <10 to 70.4 µg/L (as P) across the treatment train. Silica concentrations remained unchanged at approximately 14.4 mg/L (as SiO_2). Turbidity values ranged from 10.0 to 22.0 nephelometric turbidity unit (NTU) and averaged 16.2 NTU in source water and ranged from <0.1 to 20.0 NTU and averaged 3.7 NTU in the filter effluent. Turbidity in the filter effluent was attributable to either the particles that broke through the filters or the soluble iron that precipitated following sampling. No significant levels of sulfate were detected in source water or across the treatment train.

4.5.2 Backwash Water Sampling. Table 4-9 summarizes the analytical results from nine backwash wastewater sampling events taking place from September 20, 2005, through July 13, 2006. The samples collected on November 29, 2005 were not included in the table due to three consecutive backwash cycles inadvertently triggered by the operator prior to sampling. For the first two sampling events, grab samples were taken for pH, turbidity, TDS, and soluble arsenic, iron, and manganese analyses. Soluble arsenic, iron, and manganese concentrations ranged from 6.3 to 12.2 µg/L, from <0.025 to 0.59 mg/L, and from 14.9 to 22.6 µg/L, respectively, which, in general, were similar to those in the contact tank water used for backwashing.

Starting from November 15, 2005, backwash wastewater samples were collected using the modified sampling procedure discussed in Section 3.3.4. Turbidity was replaced by TSS, and total arsenic, iron, and manganese were added to the analyte list. Total arsenic, iron, and manganese concentrations in backwash wastewater ranged from 11.7 to 322 µg/L, from 0.27 to 37.1 mg/L, and from 16.5 to 32.9 µg/L, and averaged 97.6 µg/L, 9.8 mg/L, and 22.6 µg/L, respectively. The TSS levels ranged from 2.0 to 70.0 mg/L and averaged 13.2 mg/L. The uncharacteristically low TSS levels in the backwash wastewater samples were thought to have been caused, and confirmed by the operator, by insufficient mixing of solids/water mixtures in the 32-gal container before sampling. The operator believed, however, that the contents in the containers were thoroughly mixed before sampling for total arsenic, iron, and manganese. Assuming 70.0 mg/L of TSS in 300 gal of backwash wastewater produced by one vessel, approximately 79 g (0.18 lb) of solids would have been discharged to the septic system, with the solids containing 111 mg of arsenic, 11.1 g of iron, and 25.7 mg of manganese. The soluble arsenic, iron, and manganese concentrations were similar to those prior to November 15, 2005.

Table 4-10 presents the total metal results of backwash solid samples collected from Vessel B on July 13, 2006. Arsenic, iron, and manganese levels averaged 3.6 mg/g, 282 mg/g, and 0.2 mg/g, respectively. Assuming that 79 g of solids was produced by each vessel, the amount of arsenic, iron, and manganese existed in the solids would be 284 mg, 22.3 g, and 15.8 mg, respectively, which were within the ballpark of the values calculated based on the analysis of backwash wastewater samples. Total phosphorous in the backwash solids also was noteworthy at an average of 25.7 mg/g.

4.5.3 Distribution System Water Sampling. Table 4-11 summarizes the results of the distribution system water sampling events. The water quality was similar among the three sampling locations in the distribution system. As shown in the table, the stagnation times before the samples were taken averaged 10.1 hr. There was no major change in pH values before (i.e., average 7.4) and after (i.e., average 7.5) the system became operational. Alkalinity levels also remained approximately the same before (i.e., average 374 mg/L [as $CaCO_3$]) and after (i.e., average 360 mg/L [as $CaCO_3$]) system startup.

Arsenic concentrations in the baseline samples ranged from 9.5 to 18.0 µg/L and averaged 15.0 µg/L. These values were slightly lower than those in the historical raw water samples (i.e., from 16.0 to 25.0 µg/L and averaged 20.4 µg/L) shown in Table 4-1. After system startup, total arsenic concentrations in the samples collected from August 30 through October 18, 2005, (i.e., Events 2 to 4) were high, ranging from 11.9 to 23.3 µg/L and averaging 17.9. These high values were attributed to malfunctioning of the chlorine addition system during this time period and that arsenic concentrations following the pressure filters also were high. For the samples collected with proper operation of the chlorine addition system (i.e., Events 1, 5-13), arsenic concentrations were reduced to <10 µg/L at each of the three sampling locations, except for two outliers at DS1 on December 13, 2005, and January 17, 2006. In general, total arsenic levels in the distribution system mirrored those in the treated water. Excluding the data points taken during Events 2 to 4 and Events 6 and 7 at DS1, the average arsenic level in the distribution system was slightly higher than that at the entry point (i.e., 7.1 versus 4.3 µg/L), suggesting some solubilization, destabilization, and/or desoprtion of arsenic-laden particles/scales in the distribution system (Lytle, 2005).

Average iron concentrations remained below the MDL of 25 µg/L, before and after the baseline samples. Before system startup, iron, existing mostly in the soluble form, was removed by the softener units before entering the distribution system. After system startup, iron, existing mostly in the particulate form, was filtered by the pressure filters and, possibly, the softener units. The manganese levels averaged 1.4 µg/L

Table 4-9. Backwash Wastewater Sampling Results

Sampling Event		BW1 (Tank A)											BW2 (Tank B)										
		pH	Turbidity	TDS	TSS	Total As	Soluble As	Particulate As	Total Fe	Soluble Fe	Total Mn	Soluble Mn	pH	Turbidity	TDS	TSS	Total As	Soluble As	Particulate As	Total Fe	Soluble Fe	Total Mn	Soluble Mn
No.	Date[(a)]	S.U.	NTU	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	S.U.	NTU	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
1	09/20/05	7.5	150	358	NA	NA	7.0	NA	NA	<25	NA	14.9	7.5	20.0	356	NA	NA	6.3	NA	NA	<25	NA	15.0
2	10/11/05	7.3	68.0	386	NA	NA	7.9	NA	NA	593	NA	22.6	7.5	4.5	332	NA	NA	12.2	NA	NA	116	NA	15.3
3	01/10/06[(b)]	7.5	NA	320	12.0	121	6.7	114	13,543	141	25.7	20.6	7.7	NA	304	5.0	45.5	9.6	35.9	4,486	223	22.1	20.1
4	02/07/06	7.8	NA	314	4.0	77.8	7.3	70.6	5,199	<25	20.3	18.8	7.7	NA	304	8.0	191	8.2	183	9,494	141	23.3	18.5
5	03/07/06	7.5	NA	314	25.0	163	4.9	158	23,077	150	25.8	19.4	7.5	NA	304	23.0	132	7.9	124	19,191	561	23.9	18.1
6	04/04/06	7.5	NA	304	4.0	73.2	6.5	66.7	4,373	58.6	21.7	20.1	7.5	NA	306	4.0	13.4	9.3	4.1	265	128	20.6	20.5
7	05/24/06	7.4	NA	328	7.0	11.7	8.2	3.5	405	142	17.1	16.5	7.4	NA	324	2.0	36.3	9.1	27.2	2,390	130	16.5	16.2
8	06/06/06	7.5	NA	314	6.0	15.4	7.6	7.8	742	156	21.2	21.5	7.4	NA	304	2.0	66.5	7.7	58.8	6,564	362	23.1	19.9
9	07/13/06	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	7.5	NA	380	70.0	322	3.8	318	37,099	47.3	32.9	14.0

(a) Backwash wastewater samples not taken in July and August 2005 due to lack of a sample tap, or in December 2005 due to Christmas holidays.
(b) Modified backwash procedures implemented since November 15, 2005.
TDS = total dissolved solids; NS = not sampled

Table 4-10. Backwash Solids Sample ICP/MS Results

Date:Location[(a)]	Mg	Al	Si	P	Ca	V	Mn	Fe	Ni	Cu	Zn	As	Cd	Sb	Ba	Pb	Fe/As
	mg/g	mg/g	µg/g	mg/g	mg/g	µg/g	mg/g	mg/g	µg/g	µg/g	µg/g	mg/g	µg/g	µg/g	mg/g	µg/g	Ratio
07/13/06:Vessel B	17.0	1.2	9,698	25.7	59.9	<5	0.2	282	5.0	8,832	936	3.6	<5	<5	4.6	13.3	78

(a) Solid samples not taken for Vessel A.

Note: Data representing averages of triplicate analyses.

Table 4-11. Distribution Sampling Results

Sampling Date		As after TT	DS1 Second Floor Suite non-LCR								DS2 Shower Room A Wing LCR								DS3 Large Suite B Wing LCR							
			Stagnation Time	pH	Alkalinity	As	Fe	Mn	Pb	Cu	Stagnation Time	pH	Alkalinity	As	Fe	Mn	Pb	Cu	Stagnation Time	pH	Alkalinity	As	Fe	Mn	Pb	Cu
No.	Date	µg/L	hrs	S.U.	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	hrs	S.U.	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	hrs	S.U.	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L
BL1	03/23/05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	7.2	367	14.8	37	14.2	5.4	126	NA	7.2	376	17.1	<25	0.6	0.8	93.3
BL2	04/20/05	NA	11.0	7.6	386	14.7	<25	0.4	<0.1	51.9	11.0	7.6	395	15.6	<25	0.1	0.1	13.8	11.0	7.6	382	16.8	<25	0.1	0.4	38.2
BL3	05/31/05	NA	NA	7.2	381	9.5	<25	0.2	0.4	103	NA	7.3	385	14.8	<25	<0.1	<0.1	4.4	NA	7.3	381	15.2	<25	<0.1	0.5	77.1
BL4	06/21/05	NA	9.2	7.5	330	13.9	<25	0.2	0.1	15.2	9.1	7.5	365	18.0	<25	0.2	<0.1	13.9	9.3	7.5	361	14.3	<25	0.5	0.1	4.1
Average		**NA**	**10.1**	**7.4**	**366**	**12.7**	**<25**	**0.3**	**0.2**	**56.8**	**10.1**	**7.4**	**378**	**15.8**	**<25**	**3.6**	**1.4**	**39.5**	**10.2**	**7.4**	**375**	**15.8**	**<25**	**0.3**	**0.4**	**53.2**
1	07/27/05	5.0	9.0	7.4	352	5.9	<25	0.3	1.1	111.0	9.0	7.4	361	5.4	<25	<0.1	0.1	7.2	9.0	7.4	352	6.6	<25	<0.1	0.2	17.9
2	08/30/05[(a)]	18.0[(b)]	9.3	7.1	361	18.0[(b)]	<25	<0.1	<0.1	29.6	9.0	7.3	370	18.2[(b)]	<25	0.2	0.1	6.6	9.2	7.2	352	16.2[(b)]	<25	0.3	0.4	38.4
3	09/28/05[(a)]	16.6[(b)]	10.0	7.3	365	11.9[(b)]	<25	0.1	0.9	57.9	9.3	7.3	374	16.9[(b)]	<25	0.4	0.6	23.6	9.3	7.4	374	17.1[(b)]	<25	0.2	1.0	49.2
4	10/18/05[(a)]	10.9[(b)]	9.0	7.4	360	15.5[(b)]	<25	<0.1	0.3	33.1	9.2	7.4	365	16.9[(b)]	<25	<0.1	<0.1	4.7	9.0	7.4	361	23.3[(b)]	<25	0.1	0.4	14.2
5	11/29/05	2.6	9.2	7.5	352	6.9	<25	0.3	0.3	54.6	9.1	7.7	352	3.6	<25	0.1	0.2	23.5	9.0	7.6	352	7.5	<25	0.4	1.7	45.7
6	12/13/05	3.2	9.2	7.7	370	18.6[(b)]	<25	<0.1	0.2	49.8	9.0	7.5	365	6.7	<25	0.2	0.5	29.0	9.1	7.8	374	6.2	<25	0.2	0.8	41.9
7	01/17/06	2.9	9.6	7.4	365	17.7[(b)]	<25	0.3	0.9	95.7	9.7	7.5	356	3.1	<25	<0.1	0.5	160	9.8	7.5	356	8.8	<25	0.4	2.5	38.6
8	02/14/06	3.9	12.3	7.6	358	6.3	33	<0.1	<0.1	61.3	9.3	7.6	358	5.8	89	<0.1	0.2	23.6	9.5	7.6	354	8.2	<25	0.1	0.2	28.6
9	03/13/06	2.9	9.8	7.6	360	3.9	<25	<0.1	0.3	223	9.0	7.7	351	3.9	<25	<0.1	8.3	148	9.8	7.6	356	7.0	<25	0.5	1.6	131
10	04/11/06	6.4	9.6	7.5	378	6.0	<25	0.3	0.8	58.5	9.4	7.5	369	4.3	<25	0.1	0.1	36.3	9.5	7.5	369	5.3	<25	0.2	0.5	232
11	05/09/06	6.6	9.7	7.5	347	6.4	<25	<0.1	<0.1	30.7	9.5	7.6	343	6.0	<25	<0.1	<0.1	13.6	9.6	7.5	351	6.4	<25	<0.1	0.2	17.8
12	06/12/06	5.4	9.1	7.3	364	6.9	<25	<0.1	0.3	152	9.0	7.3	360	5.1	<25	0.1	0.2	39.2	9.2	7.4	351	6.3	<25	0.5	1.9	199
13	07/18/06	4.5	NA	7.5	347	4.7	<25	0.1	<0.1	49.1	9.8	7.6	363	5.1	<25	0.5	0.7	74.5	9.7	7.4	363	5.7	<25	0.4	2.3	67.3
Average		**4.3**	**9.6**	**7.4**	**360**	**5.9**	**<25**	**0.1**	**0.4**	**77.4**	**9.2**	**7.5**	**361**	**4.9**	**<25**	**0.1**	**0.9**	**45.3**	**9.3**	**7.5**	**359**	**6.8**	**<25**	**0.3**	**1.0**	**71.0**

(a) Chlorine pump not operational through 11/07/05 resulting in incomplete treatment.
(b) Results excluded from "average" calculations.
Lead action level = 15 µg/L; copper action level = 1,300 µg/L.
LCR = lead and copper rule sampling location; BL = Baseline Sampling; NA = not analyzed.
Note: 11 samples taken after softening system.

in the baseline samples and decreased to an average of 0.2 μg/L after system startup. Although little was removed by the pressure filters, manganese existing almost entirely in the soluble form was removed by the softener units.

Lead levels in the distribution system ranged from less than the method reporting limit of 0.1 μg/L to 8.3 μg/L both before and after system startup. Copper concentrations before system startup ranged from 4.1 to 126 μg/L; copper concentrations after system startup ranged from 4.7 to 232 μg/L. None of the lead and copper results exceeded the corresponding action levels of 15 and 1,300 μg/L. Factors that may increase the solubility of lead and copper in the distribution system include low pH, high temperature, and soft water with fewer dissolved minerals. The arsenic removal system did not appear to have exerted any impact on the lead and copper levels in the distribution system.

4.6 System Cost

The cost of the system was evaluated based on the capital cost per gpm (or gpd) of design capacity and the O&M cost per 1,000 gal of water treated. The evaluation required the tracking of the capital cost for equipment, site engineering, and installation and the O&M cost for chemical supply, electrical power use, and labor. However, the cost associated with the installation of an emergency shower and an eyewash station required for NaClO chemical handling as part of building improvements was paid for by Vintage on the Ponds and, therefore, not included in the treatment system.

4.6.1 Capital Cost. The capital investment was $60,500, which included $19,790 for equipment, $20,580 for site engineering, and $20,130 for installation. Table 4-12 presents the breakdown of the capital cost provided by the vendor in its proposal to Battelle dated March 15, 2005. The equipment cost was about 33% of the total capital investment for a contact tank, two pressure filtration vessels, Macrolite® media, distributors, process valves and piping, instrumentation and controls, a chemical feed system (including a flow-paced pump and a tapered chemical storage tank with a secondary containment), additional sample taps, totalizer/meters, shipping, and equipment assembly labor.

The engineering cost included the cost for preparing a process design report and required engineering plans, including a general arrangement drawing, piping and instrumentation diagrams (P&IDs), interconnecting piping layouts, tank fill details, an electrical on-line diagram, and other associated drawings. After certification by an Ohio-registered professional engineer, the plans were submitted to WDNR for permit review and approval (Section 4.3.1). The engineering cost was $20,580, which was 34% of the total capital investment.

The installation cost included the cost for labor and materials for system unloading and anchoring, plumbing, and mechanical and electrical connections (Section 4.3.3). The installation cost was $20,130, or 33% of the total capital investment.

Using the system's rated capacity of 45 gpm (or 64,800 gpd), the capital cost was normalized to be $1,344/gpm (or $0.93/gpd). The capital cost of $60,500 was converted to an annualized cost of $5,710/year using a capital recovery factor of 0.09439 based on a 7% interest rate and a 20-year return. Assuming that the system was operated 24 hours a day, 7 days a week at the design flow rate of 45 gpm to produce 23,600,000 gal of water per year, the unit capital cost would be $0.24/1,000 gal. However, since the system treated 2,500,000 gal in a 14-month period (see Table 4-4), corresponding to an annual production of 2,200,000 gal, the unit capital cost was increased to $2.61/1,000 gal at this reduced rate of production.

Table 4-12. Summary of Capital Investment for Vintage on the Ponds Treatment System

Description	Quantity	Cost	% of Capital Investment Cost
Equipment Cost			
Tanks	3	\$2,500	–
Media	3.5 ft^3/vessel	\$1,540	–
Distributors	2	\$175	–
Process Valves and Piping	1	\$2,100	–
Chemical Feed System	1	\$2,405	–
Instrumentation and Controls	1	\$2,500	–
Additional Flow meters/Totalizers	1	\$2,400	–
Shipping	–	\$1,000	–
Labor	–	\$5,170	–
Equipment Total	–	**\$19,790**	**33%**
Engineering Cost			
Labor	–	\$19,080	–
Travel	–	\$1,500	
Engineering Total	–	**\$20,580**	**34%**
Installation Cost			
Labor	–	\$6,380	–
Travel	–	\$2,500	–
Subcontractor	–	\$11,250	–
Installation Total	–	**\$20,130**	**33%**
Total Capital Investment	–	**\$60,500**	**100%**

4.6.2 Operation and Maintenance Cost. O&M cost includes chemical supply, electricity consumption, and labor (Table 4-13). The actual consumption rate for the 12.5% NaClO stock solution was 52.9 gal for the entire study period. Incremental electricity power consumption was calculated for the chemical feed pump. The power demand was calculated based on the total operational hours of the well pump adjusted for one year, the additional power demand needed to cover the pressure loss across the filter beds, the chemical feed pump horsepower, and the unit cost from the utility bills. The routine, non-demonstration related labor activities consumed about 5 min/day, 5 days a week, as noted in Section 4.4.4. Based on this time commitment and a labor rate of \$10.75/hr, the labor cost was \$0.11/1,000 gal of water treated. In summary, the total O&M cost was approximately \$0.26/1,000 gal.

Table 4-13. O&M Cost for the Vintage on the Ponds Treatment System for One Year

Cost Category	Value	Assumption
Volume Processed (gal)	2,500,200	
Chemical Cost		
Chemical Unit Price ($/gal)	$4.14	12.5% NaClO in a 5-gal drum
Total Chemical Consumption (gal)	52.9	
Chemical Usage (gal/1,000 gal)	0.02	
Total Chemical Cost ($)	$219.00	
Unit Chemical Cost ($/1,000 gal)	$0.09	
Electricity Cost		
Electricity Unit Cost ($/kwh)	0.067	
Estimated Electricity Usage (kwh)	2,082	Calculated based on: • 16 hr/day of operation of a 0.17-hp chemical feed pump • Additional power used by well pump to overcome pressure loss across filters with pumps operating 2.4 hr/day at 40 gpm
Estimated Electricity Cost ($)	$139.49	
Estimated Power Use ($/1,000 gal)	$0.063	Calculated based on annual volume processed of 2,200,000
Labor Cost		
Average Weekly Labor (hr)	0.42	5 min/day; 5 day/wk
Total Labor (hr)	22	52 weeks
Total Labor Cost ($)	$234.78	Labor rate = $10.75/hr
Labor Cost ($/1,000 gal)	$0.11	Calculated based on annual volume processed of 2,200,000
Total O&M Cost/1,000 gal	**$0.26**	

Section 5.0: REFERENCES

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APPENDIX A

OPERATIONAL DATA

Table A-1. Daily System Operation Log Sheet

			Volume to Treatment		Pressure					Volume to Distribution		Backwash		NaOCl Application	
Week No.	Date	Time	Totalizer (gal)	Incremental Volume (gal)	Pressure Tanks (psi)	After Contact Tank (psi)	After Filters (psi)	ΔP across System (psi)	ΔP across Filters (psi)	Totalizer (kgal)	Incremental Volume (gal)	Totalizer (gal)	Wastewater Produced (gal)	NaOCl Tank Level (gal)	Average Cl_2 Dose (mg/L)
1	07/13/05	15:00	84,200	NA	NM	39	30	NA	9	13,967.2	NA	3,650	NA	1.00	NA
	07/14/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	07/15/05	14:30	93,100	8,900	NM	49	40	NA	9	13,976.1	8,900	3,650	0	0.30	1.7
	07/16/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	07/17/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
2	07/18/05	14:15	109,900	16,800	NM	39	30	NA	9	13992.4	16,300	4,020	370	0.30	0.9
	07/19/05	13:20	116,300	6,400	NM	49	29	NA	20	13998.7	6,300	4,020	0	0.30	2.4
	07/20/05	15:00	120,000	3,700	NM	41	36	NA	5	14002.0	3,300	4,370	350	0.20	2.7
	07/21/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	07/22/05	14:00	132,800	12,800	NM	42	37	NA	5	14014.7	12,700	4,370	0	0.30	1.2
	07/23/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	07/24/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
3	07/25/05	16:30	151,500	18,700	NM	43	31	NA	12	14032.9	18,200	4,730	360	0.50	1.3
	07/26/05	16:40	156,600	5,100	NM	43	31	NA	12	14037.9	5,000	4,730	0	0.10	1.0
	07/27/05	15:30	160,800	4,200	NM	41	29	NA	12	14042.1	4,200	4,730	0	0.10	1.2
	07/28/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	07/29/05	09:35	169,900	9,100	NM	39	17	NA	22	14050.8	8,700	5,090	360	0.19	1.1
	07/30/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	07/31/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
4	08/01/05	15:10	188,800	18,900	NM	39	38	NA	1	14,069.4	18,600	5,090	0	NM	NA
	08/02/05	13:00	194,600	5,800	NM	41	33	NA	8	14,074.8	5,400	5,440	350	NM	NA
	08/03/05	13:30	199,300	4,700	NM	43	25	NA	18	14,079.5	4,700	5,440	0	NM	NA
	08/04/05	12:40	203,700	4,400	NM	43	30	NA	13	14,083.8	4,300	5,440	0	NM	NA
	08/05/05	15:03	208,500	4,800	NM	41	30	NA	11	14,088.6	4,800	5,440	0	NM	NA
	08/06/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	08/07/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
5	08/08/05	16:05	223,900	15,400	NM	42	29	NA	13	14,103.5	14,900	5,790	350	0.30	1.0
	08/09/05	14:05	234,500	10,600	NM	39	12	NA	27	14,114.0	10,500	5,790	0	0.30	1.4
	08/10/05	15:30	241,200	6,700	NM	49	31	NA	18	14,120.2	6,200	6,150	360	0.10	0.8
	08/11/05	14:00	246,200	5,000	NM	48	32	NA	16	14,125.2	5,000	6,150	0	NM	NA
	08/12/05	15:05	251,200	5,000	NM	39	22	NA	17	14,130.1	4,900	6,150	0	0.10	1.0
	08/13/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	08/14/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
6	08/15/05	16:05	268,300	17,100	NM	43	23	NA	20	14,146.6	16,500	6,500	350	0.40	1.2
	08/16/05	14:30	273,000	4,700	NM	39	20	NA	19	14,151.7	5,100	6,500	0	0.20	2.1
	08/17/05	14:35	278,500	5,500	NM	44	24	NA	20	14,156.8	5,100	6,500	0	0.20	1.8
	08/18/05	08:00	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	0.10	NA
	08/19/05	13:00	288,900	10,400	NM	39	28	NA	11	14,166.8	10,000	6,860	360	0.10	0.5
	08/20/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	08/21/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
7	08/22/05	15:50	305,400	16,500	NM	42	23	NA	19	14,183.1	16,300	6,860	0	0.20	0.6
	08/23/05	15:35	310,900	5,500	NM	43	23	NA	20	14,188.2	5,100	7,220	360	0.00	0.0
	08/24/05	10:00	314,100	3,200	NM	44	24	NA	20	14,191.3	3,100	7,220	0	0.00	0.0
	08/25/05	NM	NM	NA	NM	39	NM	NA	NA	NM	NA	NM	NA	NM	NA
	08/26/05	15:15	326,100	12,000	NM	40	21	NA	19	14,203.2	11,900	7,220	0	0.00	0.0
	08/27/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	08/28/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA

Table A-1. Daily System Operation Log Sheet (Continued)

Week No.	Date	Time	Volume to Treatment		Pressure					Volume to Distribution		Backwash		NaOCl Application	
			Totalizer (gal)	Incremental Volume (gal)	Pressure Tanks (psi)	After Contact Tank (psi)	After Filters (psi)	ΔP across System (psi)	ΔP across Filters (psi)	Totalizer (kgal)	Incremental Volume (gal)	Totalizer (gal)	Wastewater Produced (gal)	NaOCl Tank Level (gal)	Average Cl_2 Dose (mg/L)
8	08/29/05	15:40	343,600	17,500	NM	39	21	NA	18	14,220.2	17,000	7,570	350	0.00	0.0
	08/30/05	16:40	349,300	5,700	NM	44	24	NA	20	14,225.8	5,600	7,570	0	0.00	0.0
	08/31/05[a]	15:30	354,100	4,800	47	40	23	24	17	14,230.6	4,800	7,570	0	0.00	0.0
	09/01/05	13:15	358,200	4,100	55	48	24	31	24	14,234.3	3,700	7,920	350	0.00	0.0
	09/02/05	16:15	364,600	6,400	48	40	21	27	19	14,240.7	6,400	7,920	0	0.00	0.0
	09/03/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	09/04/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
9	09/05/05[b]	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	09/06/05	12:30	388,000	23,400	48	43	24	24	19	14,263.4	22,700	8,300	380	0.00	0.0
	09/07/05	16:30	396,400	8,400	48	40	19	29	21	14,271.7	8,300	8,300	0	0.00	0.0
	09/08/05	16:20	403,500	7,100	48	40	20	28	20	14,278.4	6,700	8,650	350	0.00	0.0
	09/09/05	15:35	409,100	5,600	51	42	23	28	19	14,284.0	5,600	8,650	0	0.00	0.0
	09/10/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	09/11/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
10	09/12/05	16:40	430,700	21,600	47	39	22	25	NA	14,305	21,000	9,010	NA	0.00	NA
	09/13/05	14:30	436,800	6,100	54	43	25	29	18	14,311	6,000	9,010	360	0.00	0.0
	09/14/05	15:00	443,900	7,100	53	43	23	30	20	14,318	7,100	9,010	0	0.00	0.0
	09/15/05	14:30	450,500	6,600	44	39	22	22	17	14,325	6,600	9,370	360	0.00	0.0
	09/16/05	16:00	456,000	5,500	53	43	22	31	21	14,330	5,100	9,370	0	0.00	0.0
	09/17/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	09/18/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
11	09/19/05	03:45	471,000	15,000	47	44	22	25	22	14,344.6	14,800	9,370	720	0.40	1.3
	09/20/05	03:20	476,600	5,600	49	43	22	27	21	14,349.4	4,800	10,080	710	0.20	1.8
	09/21/05	03:30	481,100	4,500	49	41	22	27	19	14,353.9	4,500	10,080	0	0.00	0.0
	09/22/05	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
	09/23/05	NM	490,400	9,300	50	43	18	32	25	14,362.4	8,500	10,080	0	0.30	1.6
	09/24/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	09/25/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
12	09/26/05	11:30	503,400	13,000	52	44	23	29	21	14,375.0	12,600	10,430	350	0.00	0.0
	09/27/05	02:30	509,200	5,800	49	43	18	31	25	14,380.9	5,900	10,430	0	0.00	0.0
	09/28/05	03:30	514,200	5,000	48	41	22	26	19	14,385.9	5,000	10,430	0	0.02	0.2
	09/29/05	09:10	518,600	4,400	52	49	25	27	24	14,390.3	4,400	10,430	0	0.01	0.1
	09/30/05	04:45	526,900	8,300	53	44	24	29	20	14,396.6	6,300	12,210	1,780	0.01	0.1
	10/01/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	10/02/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
13	10/03/05	16:50	541,200	14,300	52	43	24	28	19	14,411.1	14,500	12,210	0	0.10	0.4
	10/04/05	15:00	546,200	5,000	57	45	25	32	20	14,415.7	4,600	12,560	350	0.10	1.0
	10/05/05	16:00	552,500	6,300	50	41	23	27	18	14,420.7	5,000	12,560	0	0.10	0.8
	10/06/05	12:50	557,500	5,000	55	48	20	35	28	14,425.7	5,000	12,560	0	0.10	1.0
	10/07/05	15:40	563,600	6,100	48	41	18	30	23	14,431.8	6,100	12,560	0	0.00	0.0
	10/08/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	10/09/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
14	10/10/05	16:00	576,900	13,300	53	44	20	33	24	14,444.8	13,000	12,910	350	0.20	0.8
	10/11/05	15:40	581,600	4,700	50	42	23	27	19	14,448.7	3,900	13,630	720	0.10	1.1
	10/12/05	11:30	585,100	3,500	48	40	22	26	18	14,452.2	3,500	13,630	0	0.10	1.4
	10/13/05	14:05	590,600	5,500	52	48	20	32	28	14,457.8	5,600	13,630	0	0.10	0.9
	10/14/05	15:00	595,500	4,900	54	44	25	29	19	14,462.6	4,800	13,630	0	0.00	0.0
	10/15/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	10/16/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA

Table A-1. Daily System Operation Log Sheet (Continued)

Week No.	Date	Time	Volume to Treatment		Pressure					Volume to Distribution		Backwash		NaOCl Application	
			Totalizer (gal)	Incremental Volume (gal)	Pressure Tanks (psi)	After Contact Tank (psi)	After Filters (psi)	ΔP across System (psi)	ΔP across Filters (psi)	Totalizer (kgal)	Incremental Volume (gal)	Totalizer (gal)	Wastewater Produced (gal)	NaOCl Tank Level (gal)	Average Cl_2 Dose (mg/L)
15	10/17/05	15:40	610,800	15,300	48	40	20	28	20	14,477.8	15,200	13,980	350	0.00	0.0
	10/18/05	16:50	616,100	5,300	45	39	20	25	19	14,483.1	5,300	13,980	0	0.00	0.0
	10/19/05	15:15	619,800	3,700	48	40	22	26	18	14,486.8	3,700	13,980	0	0.20	2.7
	10/20/05	14:25	624,600	4,800	50	42	25	25	17	14,491.5	4,700	13,980	0	0.10	1.0
	10/21/05	13:45	629,500	4,900	56	45	25	31	20	14,496.5	5,000	13,980	0	0.10	1.0
	10/22/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	10/23/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
16	10/24/05	16:10	642,500	13,000	55	44	30	25	14	14,509.2	12,700	14,330	350	0.20	0.8
	10/25/05	12:00	646,600	4,100	47	40	20	27	20	14,513.4	4,200	14,330	0	0.10	1.2
	10/26/05	14:00	653,900	7,300	45	40	19	26	21	14,520.1	6,700	14,330	0	0.10	0.7
	10/27/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	10/28/05[c]	14:40	664,800	10,900	48	40	23	25	17	14,530.2	10,100	14,700	370	14.50	NA
	10/29/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	10/30/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
17	10/31/05[d]	15:50	681,200	16,400	52	43	21	31	22	14,546.8	16,600	14,700	0	14.00	1.7
	11/01/05	16:20	686,800	5,600	49	42	22	27	20	14,551.6	4,800	15,050	350	14.00	
	11/02/05	15:20	696,300	9,500	56	43	28	28	15	14,556.9	5,300	15,050	0	13.50	
	11/03/05	15:50	711,400	15,100	55	48	30	25	18	14,560.8	3,900	15,050	0	13.50	
	11/04/05	15:40	715,800	4,400	53	40	19	34	21	14,565.2	4,400	15,050	0	13.50	
	11/05/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	11/06/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
18	11/07/05	16:00	731,000	15,200	53	50	29	24	21	14,579.8	14,600	15,410	360	13.25	4.8
	11/08/05	12:00	735,000	4,000	45	38	20	25	18	14,584.0	4,200	15,410	0	13.00	
	11/09/05	15:20	739,900	4,900	52	44	24	28	20	14,588.8	4,800	15,410	0	12.75	
	11/10/05	14:05	744,000	4,100	47	40	19	28	21	14,592.9	4,100	15,410	0	12.50	
	11/11/05	15:40	749,700	5,700	55	50	32	23	18	14,597.8	4,900	16,100	690	12.50	
	11/12/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	11/13/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
19	11/14/05	15:45	762,200	12,500	49	40	19	30	21	14,610.8	13,000	16,100	0	12.00	1.6
	11/15/05	16:15	767,700	5,500	51	43	22	29	21	14,615.9	5,100	16,100	0	12.00	
	11/16/05	15:30	772,200	4,500	56	49	25	31	24	14,620.4	4,500	16,100	0	12.00	
	11/17/05	14:10	776,600	4,400	50	44	26	24	18	14,624.5	4,100	16,460	360	11.75	
	11/18/05	15:05	781,200	4,600	49	43	23	26	20	14,629.2	4,700	16,460	0	11.75	
	11/19/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	11/20/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
20	11/21/05	15:10	793,600	12,400	53	47	29	24	18	14,641.7	12,500	16,460	0	11.25	2.9
	11/22/05	15:45	798,500	4,900	57	44	24	33	20	14,646.3	4,600	16,830	370	11.25	
	11/23/05	15:30	802,700	4,200	45	38	20	25	18	14,650.5	4,200	16,830	0	11.00	
	11/24/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	
	11/25/05	15:10	814,000	11,300	46	40	20	26	20	14,661.9	11,400	16,830	0	10.75	
	11/26/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	11/27/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
21	11/28/05	15:45	830,500	16,500	53	45	22	31	23	14,678.2	16,300	17,190	360	10.25	5.9
	11/29/05	12:40	835,600	5,100	55	44	30	25	14	14,682.1	3,900	18,230	1,040	10.50	
	11/30/05	15:45	840,200	4,600	50	43	23	27	20	14,686.9	4,800	18,230	0	14.50	
	12/01/05	15:45	844,800	4,600	47	40	20	27	20	14,691.5	4,600	18,230	0	14.50	
	12/02/05	15:40	850,700	5,900	48	40	19	29	21	14,697.4	5,900	18,230	0	14.25	
	12/03/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	12/04/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA

Table A-1. Daily System Operation Log Sheet (Continued)

Week No.	Date	Time	Volume to Treatment: Totalizer (gal)	Volume to Treatment: Incremental Volume (gal)	Pressure: Pressure Tanks (psi)	Pressure: After Contact Tank (psi)	Pressure: After Filters (psi)	Pressure: ΔP across System (psi)	Pressure: ΔP across Filters (psi)	Volume to Distribution: Totalizer (kgal)	Volume to Distribution: Incremental Volume (gal)	Backwash: Totalizer (gal)	Backwash: Wastewater Produced (gal)	NaOCl Application: NaOCl Tank Level (gal)	NaOCl Application: Average Cl_2 Dose (mg/L)
22	12/05/05	16:40	865,200	14,500	51	43	23	28	20	14,711.7	14,300	18,580	350	14.00	
	12/06/05	13:35	869,000	3,800	54	44	24	30	20	14,715.6	3,900	18,580	0	13.75	
	12/07/05	15:30	879,600	10,600	53	44	21	32	23	14,726.3	10,700	18,580	0	13.50	4.0
	12/08/05	14:25	889,700	10,100	54	48	30	24	18	14,736.0	9,700	18,930	350	13.00	
	12/09/05	15:00	894,700	5,000	55	45	30	25	15	14,741.2	5,200	18,930	0	13.00	
	12/10/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	12/11/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
23	12/12/05	15:30	911,600	16,900	45	39	18	27	21	14,757.9	16,700	19,220	290	12.50	
	12/13/05	13:00	916,500	4,900	49	43	23	26	20	14,762.9	5,000	19,220	0	12.50	
	12/14/05	15:00	923,600	7,100	49	41	23	26	18	14,770.0	7,100	19,220	0	12.25	2.3
	12/15/05	12:55	930,200	6,600	51	42	23	28	19	14,776.3	6,300	19,630	410	12.00	
	12/16/05	12:30	937,100	6,900	54	48	25	29	23	14,783.3	7,000	19,630	0	12.00	
	12/17/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	12/18/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
24	12/19/05	14:10	960,300	23,200	59	51	30	29	21	14,806.3	23,000	19,980	350	11.25	
	12/20/05	14:05	968,800	8,500	46	41	25	21	16	14,814.6	8,300	20,330	350	11.00	
	12/21/05	14:30	975,500	6,700	51	45	22	29	23	14,821.4	6,800	20,330	0	10.75	4.4
	12/22/05	14:40	981,600	6,100	57	50	32	25	18	14,827.5	6,100	20,330	0	10.50	
	12/23/05	14:25	987,400	5,800	52	43	10	42	33	14,833.5	6,000	20,330	0	10.25	
	12/24/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	12/25/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
25	12/26/05	15:00	1,007,000	19,600	52	48	27	25	21	14,852.8	19,300	20,680	350	10.00	
	12/27/05	14:35	1,012,500	5,500	50	42	27	23	15	14,858.4	5,600	20,680	0	14.25	
	12/28/05	15:00	1,018,400	5,900	50	43	24	26	19	14,864.0	5,600	21,040	360	14.00	3.1
	12/29/05	14:25	1,028,500	10,100	46	40	24	22	16	14,873.7	9,700	21,040	0	13.75	
	12/30/05	14:00	1,036,000	7,500	53	43	18	35	25	14,881.0	7,300	21,380	340	13.50	
	12/31/05	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	01/01/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
26	01/02/06	16:00	1,055,300	19,300	52	45	23	29	22	14,900.4	19,400	21,380	0	13.00	
	01/03/06	14:00	1,061,800	6,500	47	40	21	26	19	14,906.6	6,200	21,730	350	13.00	
	01/04/06	15:00	1,068,400	6,600	47	39	22	25	17	14,913.4	6,800	21,730	0	12.75	2.5
	01/05/06	14:30	1,072,700	4,300	56	50	30	26	20	14,917.6	4,200	21,730	0	12.50	
	01/06/06	15:30	1,079,500	6,800	49	40	22	27	18	14,924.6	7,000	21,730	0	12.50	
	01/07/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	01/08/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
27	01/09/06	15:00	1,098,900	19,400	53	44	29	24	15	14,943.8	19,200	22,100	370	12.00	
	01/10/06	15:55	1,107,000	8,100	56	50	32	24	18	14,950.4	6,600	23,350	1,250	11.75	
	01/11/06	16:30	1,113,100	6,100	57	40	20	37	20	14,956.7	6,300	23,350	0	11.50	3.0
	01/12/06	14:30	1,118,200	5,100	55	40	22	33	18	14,961.8	5,100	23,350	0	11.25	
	01/13/06	15:45	1,127,200	9,000	58	50	32	26	18	14,970.8	9,000	23,550	200	11.28	
	01/14/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	01/15/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
28	01/16/06	16:00	1,147,200	20,000	52	43	22	30	21	14,990.8	20,000	23,720	170	10.50	
	01/17/06	16:30	1,155,100	7,900	55	50	30	25	20	14,998.4	7,600	24,080	360	10.25	
	01/18/06	16:00	1,161,000	5,900	48	39	20	28	19	15,004.4	6,000	24,080	0	14.75	3.5
	01/19/06	14:25	1,166,500	5,500	53	49	30	23	19	15,009.9	5,500	24,080	0	14.50	
	01/20/06	15:20	1,172,800	6,300	48	40	22	26	18	15,015.8	5,900	24,430	350	14.25	
	01/21/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	01/22/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA

Table A-1. Daily System Operation Log Sheet (Continued)

Week No.	Date	Time	Volume to Treatment: Totalizer (gal)	Volume to Treatment: Incremental Volume (gal)	Pressure: Pressure Tanks (psi)	Pressure: After Contact Tank (psi)	Pressure: After Filters (psi)	Pressure: ΔP across System (psi)	Pressure: ΔP across Filters (psi)	Volume to Distribution: Totalizer (kgal)	Volume to Distribution: Incremental Volume (gal)	Backwash: Totalizer (gal)	Backwash: Wastewater Produced (gal)	NaOCl Application: NaOCl Tank Level (gal)	NaOCl Application: Average Cl_2 Dose (mg/L)
	01/23/06	15:20	1,190,600	17,800	52	43	23	29	20	15,033.2	17,400	24,430	0	14.00	
	01/24/06	15:00	1,195,900	5,300	46	39	21	25	18	15,038.8	5,600	24,780	350	13.75	
	01/25/06	17:15	1,203,000	7,100	54	45	30	24	15	15,045.9	7,100	24,780	0	13.50	3.1
29	01/26/06	14:25	1,211,100	8,100	51	45	21	30	24	15,052.4	6,500	24,780	0	13.50	
	01/27/06	15:10	1,219,400	8,300	54	44	28	26	16	15,060.3	7,900	25,130	350	13.25	
	01/28/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	01/29/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	01/30/06	15:25	1,235,800	16,400	55	46	30	25	16	15,076.9	16,600	25,130	0	13.00	
	01/31/06	14:00	1,241,800	6,000	56	48	30	26	18	15,082.3	5,400	25,480	350	12.75	
	02/01/06	15:30	1,247,800	6,000	45	38	18	27	20	15,088.2	5,900	25,480	0	12.50	3.4
30	02/02/06	14:40	1,255,300	7,500	47	40	22	25	18	15,093.9	5,700	25,480	0	12.50	
	02/03/06	15:20	1,262,100	6,800	48	40	20	28	20	15,100.9	6,960	25,480	0	12.25	
	02/04/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	02/05/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	02/06/06	15:20	1,278,000	15,900	49	42	24	25	18	15,116.4	15,540	25,830	350	12.00	
	02/07/06	13:10	1,283,300	5,300	58	50	28	30	22	15,121.8	5,400	25,830	0	11.75	
	02/08/06	15:30	1,292,000	8,700	47	40	19	28	21	15,129.9	8,100	26,460	630	11.50	3.5
31	02/09/06	14:05	1,298,000	6,000	55	48	28	27	20	15,135.9	6,000	26,460	0	11.25	
	02/10/06	15:30	1,303,200	5,200	56	48	30	26	18	15,141.1	5,200	26,660	200	11.25	
	02/11/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	02/12/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	02/13/06	15:45	1,318,900	15,700	44	37	22	22	15	15,156.6	15,500	26,810	150	10.75	
	02/14/06	15:25	1,324,000	5,100	55	48	31	24	17	15,161.8	5,200	26,810	0	10.50	
	02/15/06	15:55	1,328,700	4,700	45	38	20	25	18	15,166.5	4,700	26,810	0	10.50	4.3
32	02/16/06	14:25	1,332,300	3,600	48	40	24	24	16	15,169.9	3,400	27,170	360	10.25	
	02/17/06	15:40	1,339,600	7,300	53	45	21	32	24	15,177.2	7,300	27,170	0	10.00	
	02/18/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	02/19/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	02/20/06	16:15	1,356,000	16,400	50	43	26	24	17	15,193.3	16,100	27,520	350	14.25	
	02/21/06	15:00	1,361,700	5,700	48	46	28	20	18	15,199.1	5,800	27,520	0	14.00	
	02/22/06	15:30	1,370,600	8,900	59	50	31	28	19	15,208.0	8,900	27,520	0	13.75	4.2
33	02/23/06	14:30	1,377,800	7,200	58	51	32	26	19	15,215.0	7,000	27,880	360	13.50	
	02/24/06	14:30	1,384,700	6,900	49	42	20	29	22	15,222.0	7,000	27,880	0	13.25	
	02/25/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	02/26/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	02/27/06	15:30	1,405,200	20,500	56	50	32	24	18	15,242.20	20,200	28,230	350	12.75	
	02/28/06	14:15	1,410,300	5,100	52	44	22	30	22	15,247.40	5,200	28,230	0	12.50	
	03/01/06	15:15	1,415,500	5,200	58	50	33	25	17	15,252.70	5,300	28,230	0	12.50	2.7
34	03/02/06	14:15	1,421,300	5,800	45	40	18	27	22	15,258.20	5,500	28,580	350	12.25	
	03/03/06	13:30	1,427,200	5,900	46	39	20	26	19	15,264.20	6,000	28,580	0	12.25	
	03/04/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	03/05/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	03/06/06	16:30	1,443,400	16,200	56	49	30	26	19	15,280.10	15,900	28,930	350	11.75	
	03/07/06	09:10	1,446,700	3,300	58	50	30	28	20	15,283.50	3,400	28,930	0	11.50	
	03/08/06	15:30	1,454,100	7,400	46	38	20	26	18	15,290.30	6,800	29,570	640	11.25	4.2
35	03/09/06	15:10	1,459,200	5,100	46	40	21	25	19	15,295.40	5,100	29,570	0	11.00	
	03/10/06	15:20	1,464,800	5,600	48	40	18	30	22	15,301.00	5,600	29,570	0	11.00	
	03/11/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	03/12/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA

Table A-1. Daily System Operation Log Sheet (Continued)

			Volume to Treatment		Pressure					Volume to Distribution		Backwash		NaOCl Application	
Week No.	Date	Time	Totalizer (gal)	Incremental Volume (gal)	Pressure Tanks (psi)	After Contact Tank (psi)	After Filters (psi)	ΔP across System (psi)	ΔP across Filters (psi)	Totalizer (kgal)	Incremental Volume (gal)	Totalizer (gal)	Wastewater Produced (gal)	NaOCl Tank Level (gal)	Average Cl_2 Dose (mg/L)
	03/13/06	15:20	1,481,500	16,700	47	40	21	26	19	15,317.5	16,500	29,850	280	10.50	
	03/14/06	14:45	1,486,700	5,200	58	50	24	34	26	15,322.8	5,300	29,850	0	10.25	
	03/15/06	11:00	1,490,500	3,800	56	50	22	34	28	15,326.6	3,800	29,850	0	10.25	4.0
36	03/16/06	14:05	1,497,100	6,600	59	50	28	31	22	15,332.9	6,300	30,130	280	14.50	
	03/17/06	15:15	1,504,000	6,900	52	46	28	24	18	15,339.9	7,000	30,130	0	14.25	
	03/18/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	03/19/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	03/20/06	15:15	1,521,000	17,000	51	42	21	30	21	15,356.7	16,800	30,420	290	13.75	
	03/21/06	13:45	1,527,100	6,100	58	50	28	30	22	15,362.0	5,300	30,420	0	13.75	
	03/22/06	15:20	1,534,100	7,000	46	40	21	25	19	15,369.1	7,100	30,420	0	13.50	2.5
37	03/23/06	13:30	1,539,000	4,900	52	43	22	30	21	15,373.7	4,600	30,770	350	13.50	
	03/24/06	15:00	1,544,600	5,600	51	43	24	27	19	15,379.3	5,600	30,770	0	13.25	
	03/25/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	03/26/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	03/27/06	10:30	1,562,100	17,500	53	46	23	30	23	15,396.3	17,000	31,460	690	13.00	
	03/28/06	10:00	1,566,700	4,600	47	40	22	25	18	15,401.0	4,700	31,460	0	12.75	
	03/29/06	15:45	1,573,400	6,700	58	50	30	28	20	15,407.7	6,700	31,460	0	12.75	2.9
38	03/30/06	14:20	1,577,800	4,400	45	39	19	26	20	15,412.1	4,400	31,460	0	12.50	
	03/31/06	15:45	1,582,700	4,900	57	50	23	34	27	15,417.1	5,000	31,460	0	12.50	
	04/01/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	04/02/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	04/03/06	13:30	1,597,200	14,500	50	41	20	30	21	15,431.4	14,300	31,810	350	12.25	
	04/04/06	08:30	1,599,700	2,500	48	41	22	26	19	15,433.0	1,600	31,810	0	12.25	
	04/05/06	15:20	1,607,800	8,100	47	40	21	26	19	15,441.4	8,400	32,410	600	12.00	2.5
39	04/06/06	11:50	1,612,500	4,700	47	40	21	26	19	15,446.1	4,700	32,410	0	11.75	
	04/07/06	14:10	1,620,700	8,200	50	43	23	27	20	15,454.4	8,300	32,410	0	11.75	
	04/08/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	04/09/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	04/10/06	14:15	1,637,000	16,300	46	39	20	26	19	15,470.5	16,100	32,770	360	11.25	
	04/11/06	14:00	1,642,600	5,600	48	40	20	28	20	15,476.2	5,700	32,770	0	11.25	
	04/12/06	15:16	1,649,600	7,000	53	43	30	23	13	15,482.9	6,700	33,120	350	11.00	2.5
40	04/13/06	11:15	1,653,300	3,700	54	48	29	25	19	15,486.6	3,700	33,120	0	10.75	
	04/14/06	14:45	1,660,400	7,100	52	45	29	23	16	15,493.8	7,200	33,120	0	10.75	
	04/15/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	04/16/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	04/17/06	14:30	1,675,500	15,100	46	38	20	26	18	15,508.7	14,900	33,480	360	10.50	
	04/18/06	15:00	1,680,900	5,400	46	37	20	26	17	15,514.2	5,500	33,480	0	10.50	
	04/19/06	15:30	1,686,200	5,300	55	50	30	25	20	15,519.4	5,200	33,480	0	10.25	1.5
41	04/20/06	02:00	1,690,300	4,100	45	40	20	25	20	15,523.3	3,900	33,840	360	10.25	
	04/21/06	14:15	1,695,100	4,800	48	40	20	28	20	15,528.2	4,900	33,840	0	10.25	
	04/22/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	04/23/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	04/24/06	15:10	1,710,000	14,900	48	40	22	26	18	15,543.2	15,000	33,840	0	9.75	
	04/25/06	13:10	1,714,400	4,400	48	41	22	26	19	15,547.6	4,400	33,840	0	14.25	
	04/26/06	15:35	1,722,500	8,100	53	48	28	25	20	15,554.0	6,400	33,840	0	14.00	3.6
42	04/27/06	02:00	1,728,900	6,400	49	41	24	25	17	15,559.4	5,400	33,840	0	13.75	
	04/28/06	15:10	1,735,100	6,200	53	43	30	23	13	15,565.7	6,300	33,840	0	13.75	
	04/29/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	04/30/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA

Table A-1. Daily System Operation Log Sheet (Continued)

			Volume to Treatment		Pressure					Volume to Distribution		Backwash		NaOCl Application	
Week No.	Date	Time	Totalizer (gal)	Incremental Volume (gal)	Pressure Tanks (psi)	After Contact Tank (psi)	After Filters (psi)	ΔP across System (psi)	ΔP across Filters (psi)	Totalizer (kgal)	Incremental Volume (gal)	Totalizer (gal)	Wastewater Produced (gal)	NaOCl Tank Level (gal)	Average Cl_2 Dose (mg/L)
	05/01/06	16:00	1,748,900	13,800	48	40	22	26	18	15,579.7	14,000	33,840	0	13.50	
	05/02/06	11:50	1,753,500	4,600	50	43	25	25	18	15,584.3	4,600	33,840	0	13.25	
	05/03/06	15:45	1,759,600	6,100	52	42	22	30	20	15,590.1	5,800	34,170	330	13.25	2.9
43	05/04/06	14:00	1,763,300	3,700	52	44	28	24	16	15,593.9	3,800	34,170	0	13.00	
	05/05/06	15:40	1,769,200	5,900	48	40	21	27	19	15,599.4	5,500	34,170	0	13.00	
	05/06/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	05/07/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	05/08/06	16:00	1,784,300	15,100	54	45	30	24	15	15,614.7	15,300	34,520	350	12.75	
	05/09/06	14:45	1,788,900	4,600	48	40	20	28	20	15,619.4	4,700	34,520	0	12.50	
	05/10/06	14:50	1,795,200	6,300	53	46	30	23	16	15,625.8	6,400	34,520	0	12.50	1.3
44	05/11/06	13:50	1,800,100	4,900	45	39	19	26	20	15,630.8	5,000	34,520	0	12.50	
	05/12/06	15:05	1,806,900	6,800	50	42	24	26	18	15,637.3	6,500	34,870	350	12.50	
	05/13/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	05/14/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	05/15/06	14:00	1,822,900	16,000	55	48	21	34	27	15,653.5	16,200	34,870	0	12.25	
	05/16/06	13:00	1,828,100	5,200	54	48	28	26	20	15,658.3	4,800	35,240	370	12.25	
	05/17/06	13:20	1,832,900	4,800	58	46	28	30	18	15,663.2	4,900	35,240	0	11.75	3.0
45	05/18/06	12:40	1,837,800	4,900	45	38	22	23	16	15,668.2	5,000	35,240	0	11.75	
	05/19/06	14:00	1,843,000	5,200	56	49	30	26	19	15,673.5	5,300	35,240	0	11.75	
	05/20/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	05/21/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	05/22/06	10:30	1,859,200	16,200	48	40	20	28	20	15,689.6	16,100	35,590	350	11.50	
	05/23/06	13:20	1,867,500	8,300	48	40	20	28	20	15,697.9	8,300	35,590	0	11.50	
	05/24/06	13:10	1,874,700	7,200	52	42	19	33	23	15,704.9	7,000	35,930	340	11.25	3.7
46	05/25/06	13:10	1,884,300	9,600	50	42	24	26	18	15,713.9	9,000	36,600	670	10.75	
	05/26/06	14:18	1,891,400	7,100	48	40	21	27	19	15,721.1	7,200	36,600	0	10.50	
	05/27/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	05/28/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	05/29/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	
	05/30/06	14:10	1,911,500	20,100	58	50	30	28	20	15,741.1	20,000	36,940	340	10.25	
	05/31/06	15:30	1,917,200	5,700	54	45	23	31	22	15,746.9	5,800	36,940	0	10.25	1.5
47	06/01/06	14:20	1,924,900	7,700	54	48	28	26	20	15,754.3	7,400	37,280	340	10.00	
	06/02/06	15:20	1,931,400	6,500	54	48	24	30	24	15,760.9	6,600	37,280	0	10.00	
	06/03/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	06/04/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	06/05/06	NM	1,949,300	17,900	55	48	28	27	20	15,778.7	17,800	37,620	340	9.50	
	06/06/06	14:10	1,953,200	3,900	48	40	20	28	20	15,782.7	4,000	37,620	0	9.50	
	06/07/06	15:30	1,961,500	8,300	48	40	20	28	20	15,790.3	7,600	38,240	620	14.00	3.5
48	06/08/06	14:20	1,966,600	5,100	49	42	20	29	22	15,795.5	5,200	38,240	0	13.75	
	06/09/06	15:20	1,974,700	8,100	55	49	30	25	19	15,803.7	8,200	38,240	0	13.50	
	06/10/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	06/11/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	06/12/06	14:00	1,998,900	24,200	47	39	18	29	21	15,827.5	23,800	38,930	690	13.25	
	06/13/06	14:10	2,014,100	15,200	52	46	26	26	20	15,842.9	15,400	38,930	0	12.75	
	06/14/06	15:40	2,024,300	10,200	51	44	24	27	20	15,852.8	9,900	39,270	340	12.75	3.1
49	06/15/06	13:50	2,029,600	5,300	55	50	28	27	22	15,858.3	5,500	39,270	0	12.25	
	06/16/06	15:00	2,036,900	7,300	48	40	20	28	20	15,865.7	7,400	39,270	0	12.25	
	06/17/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	06/18/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA

Table A-1. Daily System Operation Log Sheet (Continued)

Week No.	Date	Time	Volume to Treatment: Totalizer (gal)	Volume to Treatment: Incremental Volume (gal)	Pressure: Pressure Tanks (psi)	Pressure: After Contact Tank (psi)	Pressure: After Filters (psi)	Pressure: ΔP across System (psi)	Pressure: ΔP across Filters (psi)	Volume to Distribution: Totalizer (kgal)	Volume to Distribution: Incremental Volume (gal)	Backwash: Totalizer (gal)	Backwash: Wastewater Produced (gal)	NaOCl Application: NaOCl Tank Level (gal)	NaOCl Application: Average Cl_2 Dose (mg/L)
	06/19/06	15:15	2,053,000	16,100	50	42	23	27	19	15,881.6	15,900	39,620	350	12.25	
	06/20/06	13:20	2,059,500	6,500	58	50	31	27	19	15,887.8	6,200	39,970	350	12.25	
	06/21/06	15:30	2,066,200	6,700	48	44	29	19	15	15,893.6	5,800	39,970	0	1.00	2.6
50	06/22/06	14:15	2,081,800	15,600	56	49	30	26	19	15,898.9	5,300	39,970	0	11.75	
	06/23/06	14:10	2,087,600	5,800	50	42	21	29	21	15,904.9	6,000	39,970	0	11.50	
	06/24/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	06/25/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	06/26/06	15:30	2,116,600	29,000	52	43	28	24	15	15,933.4	28,500	40,650	680	11.25	
	06/27/06	15:05	2,121,600	5,000	57	49	32	25	17	15,938.4	5,000	40,650	0	11.25	3.2
	06/28/06	15:35	2,128,000	6,400	55	50	30	25	20	15,945.0	6,600	40,650	0	11.00	
51	06/29/06	14:45	2,135,400	7,400	47	38	16	31	22	15,952.2	7,200	40,970	320	10.75	
	06/30/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	
	07/01/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	07/02/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	07/03/06	16:00	2,162,100	26,700	52	53	23	29	30	15,978.6	26,400	41,370	400	10.75	
	07/04/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	
	07/05/06	15:40	2,179,800	17,700	58	47	30	28	17	15,996.2	17,600	41,670	300	10.75	NA
52	07/06/06	13:10	2,186,600	6,800	45	39	21	24	18	16,003.1	6,900	41,670	0	10.75	
	07/07/06	15:30	2,195,800	9,200	53	44	30	23	14	16,012.3	9,200	41,670	0	10.75	
	07/08/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	07/09/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	07/10/06	13:50	2,217,800	22,000	52	42	22	30	20	16,034.3	22,000	42,010	340	10.75	
	07/11/06	15:15	2,231,700	13,900	52	44	16	36	28	16,045.5	11,200	43,682	1,672	9.50	
	07/12/06	07:50	2,240,100	8,400	53	43	24	29	19	16,055.5	10,000	43,682	0	14.50	5.5
53	07/13/06	09:15	2,253,900	13,800	60	50	29	31	21	16,068.5	13,000	44,033	351	14.00	
	07/14/06	11:20	2,271,500	17,600	52	42	24	28	18	16,085.8	17,300	44,347	314	13.75	
	07/15/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	07/16/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	07/17/06	14:30	2,290,500	19,000	50	40	24	26	16	16,104.8	19,000	44,700	354	13.50	
	07/18/06	10:30	2,294,800	4,300	54	48	30	24	18	16,109.2	4,400	44,700	0	13.25	
	07/19/06	15:25	2,302,900	8,100	48	40	22	26	18	16,117.5	8,300	44,700	0	13.25	3.4
54	07/20/06	14:00	2,308,500	5,600	46	40	20	26	20	16,123.1	5,600	44,700	0	13.00	
	07/21/06	13:40	2,316,800	8,300	49	40	10	39	30	16,131.2	8,100	45,030	330	12.75	
	07/22/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	07/23/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	07/24/06	15:20	2,335,100	18,300	52	44	30	22	14	16,149.3	18,100	45,380	350	12.50	
	07/25/06	15:50	2,340,800	5,700	49	40	20	29	20	16,155.2	5,900	45,380	0	12.50	
	07/26/06	15:30	2,346,400	5,600	47	38	18	29	20	16,160.8	5,600	45,380	0	12.25	3.2
55	07/27/06	14:15	2,353,200	6,800	52	45	21	31	24	16,167.3	6,500	45,730	350	12.00	
	07/28/06	15:40	2,362,600	9,400	52	42	23	29	19	16,176.8	9,500	45,730	0	11.75	
	07/29/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	07/30/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	07/31/06	16:10	2,390,500	27,900	54	44	24	30	20	16,204.8	28,000	46,080	350	11.25	
	08/01/06	13:50	2,400,100	9,600	55	48	29	26	19	16,211.9	7,100	46,400	320	11.00	
	08/02/06	14:15	2,408,800	8,700	51	38	25	26	13	16,220.5	8,600	46,740	340	10.50	4.0
56	08/03/06	14:00	2,420,800	12,000	46	39	20	26	19	16,231.8	11,300	46,740	0	10.25	
	08/04/06	14:00	2,427,900	7,100	52	44	19	33	25	16,239.0	7,200	46,740	0	10.00	
	08/05/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	08/06/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA

Table A-1. Daily System Operation Log Sheet (Continued)

Week No.	Date	Time	Volume to Treatment		Pressure					Volume to Distribution		Backwash		NaOCl Application	
			Totalizer (gal)	Incremental Volume (gal)	Pressure Tanks (psi)	After Contact Tank (psi)	After Filters (psi)	ΔP across System (psi)	ΔP across Filters (psi)	Totalizer (kgal)	Incremental Volume (gal)	Totalizer (gal)	Wastewater Produced (gal)	NaOCl Tank Level (gal)	Average Cl_2 Dose (mg/L)
	08/07/06	14:00	2,453,700	25,800	45	38	21	24	17	16,264.6	25,640	46,900	160	10.00	
	08/08/06	14:10	2,467,800	14,100	48	40	21	27	19	16,278.2	13,580	47,420	520	NM	
	08/09/06	15:00	2,479,400	11,600	48	40	18	30	22	16,290.1	11,880	47,730	310	NM	NA
57	08/10/06	14:55	2,498,600	19,200	53	47	30	23	17	16,309.2	19,100	48,050	320	NM	
	08/11/06	15:40	2,504,000	5,400	43	38	18	25	20	16,314.7	5,500	48,050	0	NM	
	08/12/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	08/13/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	08/14/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	08/15/06	13:30	2,530,900	26,900	52	41	19	33	22	16,341.7	27,000	48,380	330	12.25	
	08/16/06	16:00	2,537,300	6,400	54	44	23	31	21	16,348.1	6,400	48,380	0	12.00	5.0
58	08/17/06	13:50	2,542,800	5,500	50	40	25	25	15	16,353.8	5,700	48,380	0	11.75	
	08/18/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	08/19/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	08/20/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	08/21/06	16:10	2,569,900	27,100	51	42	28	23	14	16,381.2	27,400	48,380	0	11.25	
	08/22/06	15:15	2,579,800	9,900	51	41	23	28	18	16,391.3	10,100	48,380	0	10.75	
	08/23/06	15:45	2,590,800	11,000	55	48	26	29	22	16,402.4	11,100	48,380	0	10.50	4.1
59	08/24/06	14:15	2,597,900	7,100	42	35	20	22	15	16,409.4	7,000	48,670	290	10.25	
	08/25/06	14:55	2,605,900	8,000	50	40	25	25	15	16,417.2	7,800	48,990	320	10.00	
	08/26/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	08/27/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	08/28/06	15:45	2,630,500	24,600	44	37	18	26	19	16,441.9	24,700	49,320	330	8.25	
	08/29/06	14:00	2,635,600	5,100	50	40	21	29	19	16,447.0	5,100	49,320	0	13.25	
	08/30/06	15:15	2,643,400	7,800	47	39	19	28	20	16,454.7	7,700	49,630	310	12.75	5.9
60	08/31/06	14:05	2,649,600	6,200	53	45	21	32	24	16,461.0	6,300	49,630	0	12.50	
	09/01/06	13:40	2,655,900	6,300	50	42	22	28	20	16,467.4	6,400	49,630	0	12.25	
	09/02/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA
	09/03/06	NM	NM	NA	NM	NM	NM	NA	NA	NM	NA	NM	NA	NM	NA

Note:

(a) On 08/31/05, pressure reading of the four pressure tanks started being recorded.

(b) Labor day holiday.

(c) Change in NaOCl tank level recorded up to 10/28/06 when actual NaOCl tank level started being recorded.

(d) Flow meters, one on treated water line and one on backwash line, installed on 09/20/06 but readings not recorded until 10/31/06.

NM = not measureed; NA = not available.

APPENDIX B

ANALYTICAL DATA

Analytical Results from Treatment Plant Sampling at Delavan, WI

Sampling Date		07/12/05			07/19/05[(a)]				07/26/05[(a)]				08/02/05				08/09/05		
Sampling Location / Parameter	Unit	IN	AC	TT	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TT
Alkalinity (as $CaCO_3$)	mg/L	352	352	352	365	361	365	365	370	365	361	374	352	352	356	352	356	361	356
Fluoride	mg/L	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Sulfate	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Nitrate (as N)	mg/L	0.1	<0.05	<0.05	0.1	0.1	0.1	0.2	0.1	0.1	0.2	0.1	<0.05	0.08	<0.05	<0.05	<0.05	<0.05	0.2
Total Kjeldahl Nitrogen	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ammonia (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Orthophosphate (as PO_4)	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Total P (as PO_4)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	13.9	14.2	13.8	14.2	14.2	14.0	14.2	14.5	14.1	14.2	14.0	14.0	14.3	14.5	14.1	15.1	14.9	14.7
Turbidity	NTU	14.0	1.7	0.3	18.0	1.8	0.6	0.2	16.0	2.4	2.3	1.3	14.0	2.2	0.7	0.5	10.0	2.3	0.3
TOC	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	7.4	7.4	7.5	7.4	7.4	7.4	7.5	7.5	7.7	7.6	7.3	7.5	7.6	7.4	7.5	7.6	7.6	7.6
Temperature	℃	14.1	15.5	15.4	13.9	13.2	13.1	14.5	13.3	14.1	13.8	12.9	13.8	13.5	12.7	15.0	14.3	13.0	13.4
DO	mg/L	0.8	1.9	1.7	2.6	1.2	3.2	3.9	0.0	0.0	0.0	3.2	2.1	3.1	1.7	2.1	0.0	0.0	0.0
ORP	mV	-52	174	241	-60	73	221	284	-35	40	34	43	-51	49	49	73	127	35	98
Free Chlorine (as Cl_2)	mg/L	-	-	<0.02	-	<0.02	<0.02	<0.02	-	<0.02	<0.02	<0.02	-	<0.02	<0.02	<0.02	-	<0.02	<0.02
Total Chlorine (as Cl_2)	mg/L	-	-	0.1	-	0.3	0.2	0.2	-	<0.1	<0.1	<0.1	-	0.2	<0.1	0.1	-	<0.1	0.1
Total Hardness (as $CaCO_3$)	mg/L	304	318	329	-	-	-	-	-	-	-	-	-	-	-	-	295	290	297
Ca Hardness (as $CaCO_3$)	mg/L	162	170	175	-	-	-	-	-	-	-	-	-	-	-	-	147	144	149
Mg Hardness (as $CaCO_3$)	mg/L	141	148	153	-	-	-	-	-	-	-	-	-	-	-	-	148	146	149
As (total)	µg/L	18.6	20.5	7.6	21.7	16.6	3.2	2.9	17.4	16.4	5.3	4.7	15.8	15.6	4.9	4.5	17.8	19.1	6.0
As (soluble)	µg/L	19.2	7.7	7.7	-	-	-	-	-	-	-	-	-	-	-	-	18.4	10.4	6.4
As (particulate)	µg/L	<0.1	12.8	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	8.7	0.4
As (III)	µg/L	18.6	5.0	5.8	-	-	-	-	-	-	-	-	-	-	-	-	17.6	5.8	5.9
As (V)	µg/L	0.6	2.7	1.8	-	-	-	-	-	-	-	-	-	-	-	-	0.8	2.9	0.5
Fe (total)	µg/L	1,557	1,419	<25	1,471	1,446	<25	<25	1,388	1,349	179	143	1,472	1,311	100	94	1,183	1,237	39
Fe (soluble)	µg/L	1,509	130	<25	-	-	-	-	-	-	-	-	-	-	-	-	996	385	<25
Mn (total)	µg/L	19.5	18.9	20.4	19.0	19.3	18.1	18.4	18.2	18.2	18.4	18.6	18.2	17.4	15.8	16.5	16.1	17.2	16.2
Mn (soluble)	µg/L	19.8	18.3	20.3	-	-	-	-	-	-	-	-	-	-	-	-	17.0	16.3	16.2

(a) Sampling error using the DO probe.

IN = influent; AC = after chlorination; TA = after Vessel A; TB = after Vessel B; TT = after combined effluent. NA = not available.

Analytical Results from Treatment Plant Sampling at Delavan, WI (Continued)

Sampling Date		08/16/05				08/23/05				08/30/05				09/06/05				09/13/05			
Sampling Location Parameter	Unit	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB
Alkalinity (as $CaCO_3$)	mg/L	330	352	352	356	352	352	356	356	365	352	352	356	352	361	356	361	361	356	352	361
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Kjeldahl Nitrogen	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ammonia (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Orthophosphate (as PO_4)	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Total P (as PO_4)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	14.6	14.5	15.0	14.7	13.8	14.3	14.4	14.1	16.6	16.8	16.8	16.2	15.3	14.6	14.9	14.8	14.4	14.7	14.9	14.7
Turbidity	NTU	14.0	2.0	1.4	2.3	14.7	11.3	20.4	19.0	12.0	13.0	20.0	19.0	14.0	13.0	18.0	17.0	14.0	18.0	18.0	18.0
TOC	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	7.7	7.6	7.5	7.6	7.7	7.6	7.6	7.5	7.6	7.5	7.5	7.4	7.5	7.5	7.3	7.5	7.6	7.5	7.6	7.5
Temperature	°C	13.0	13.1	13.1	13.1	13.6	13.3	13.3	13.0	15.6	12.6	13.3	12.9	16.3	13.9	14.6	14.2	14.5	13.2	13.5	13.7
DO	mg/L	3.6	3.5	1.8	1.9	2.8	2.6	2.6	2.5	2.6	3.7	1.6	1.9	2.6	2.0	2.1	1.9	2.4	2.1	3.1	2.0
ORP	mV	-40	-33	-50	-46	-49	-37	-47	-36	-36	-59	-68	-60	-22	-66	-59	-70	-68	-69	-51	-56
Free Chlorine (as Cl_2)	mg/L	-	<0.02	<0.02	<0.02	-	<0.02	<0.02	<0.02	-	<0.02	<0.02	<0.02	-	0.09	0.03	<0.02	-	<0.02	0.12	<0.02
Total Chlorine (as Cl_2)	mg/L	-	<0.1	<0.1	<0.1	-	<0.1	<0.1	<0.1	-	<0.1	<0.1	<0.1	-	<0.1	<0.1	<0.1	-	<0.1	<0.1	<0.1
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (total)	µg/L	17.5	16.8	5.5	6.3	19.0	19.1	6.7	6.8	NA	17.2	17.9	18.1	20.7	19.9	19.9	21.0	16.8	17.6	17.2	17.0
As (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (total)	µg/L	1,466	1,406	150	219	1,319	1,324	137	202	NA	1,416	1,499	1,525	1,350	1,351	1,418	1,389	1,443	1,556	1,452	1,512
Fe (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (total)	µg/L	18.4	17.9	17.9	17.9	17.4	18.0	18.2	17.9	NA	17.8	17.9	18.5	18.5	17.5	17.8	17.7	17.4	17.4	16.8	17.1
Mn (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

IN = influent; AC = after chlorination; TA = after Vessel A; TB = after Vessel B; TT = after combined effluent. NA = not available.

Analytical Results from Treatment Plant Sampling at Delavan, WI (Continued)

Sampling Date		09/20/05				09/27/05			10/04/05				10/11/05[(a)]				10/18/05			
Sampling Location Parameter	Unit	IN	AC	TA	TB	IN	AC	TT	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB
Alkalinity (as $CaCO_3$)	mg/L	352	370	374	370	361	361	365	361	374	370	374	361 361	374 370	361 361	356 356	356	356	352	365
Fluoride	mg/L	-	-	-	-	0.2	0.2	0.2	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	<1	<1	<1	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	<0.05	<0.05	<0.05	-	-	-	-	-	-	-	-	-	-	-	-
Total Kjeldahl Nitrogen	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ammonia (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Orthophosphate (as PO_4)	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-	-	-	-	-	-	-	-
Total P (as PO_4)	mg/L	-	-	-	-	-	-	-	-	-	-	-	54.5 55.0	52.5 58.8	<10 <10	<10 <10	77.2	76.7	41.2	35.8
Silica (as SiO_2)	mg/L	13.0	13.0	13.3	13.1	16.2	16.3	16.0	14.2	14.5	13.8	15.3	13.6 13.6	13.3 13.8	14.2 14.7	13.6 14.0	13.0	13.3	14.3	13.4
Turbidity	NTU	16.0	2.2	3.2	2.0	16.0	18.0	20.0	20.0	6.1	7.5	11.0	14.0 15.0	5.3 11.0	7.2 7.0	6.8 5.5	18.0	2.7	11.0	9.9
TOC	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	7.3	7.2	7.4	7.4	7.5	7.5	7.7	7.4	7.5	7.5	7.4	8.1	8.0	8.0	8.1	7.4	7.4	7.4	7.4
Temperature	°C	15.1	16.0	15.5	14.9	13.5	13.4	13.9	14.0	13.8	13.5	13.8	15.1	14.4	14.0	14.1	15.2	15.5	15.1	15.3
DO	mg/L	1.9	2.7	2.4	2.1	2.0	2.0	3.9	2.8	2.1	2.3	2.1	2.7	3.1	2.9	2.9	2.3	2.1	2.3	2.3
ORP	mV	-73	-18	-27	-28	-81	-76	-67	-81	-53	-50	-60	-74	-49	-34	-19	-74	-66	-59	-31
Free Chlorine (as Cl_2)	mg/L	-	<0.02	<0.02	<0.02	-	<0.02	<0.02	-	<0.02	<0.02	<0.02	-	<0.02	<0.02	0.04	-	<0.02	<0.02	<0.02
Total Chlorine (as Cl_2)	mg/L	-	<0.1	<0.1	<0.1	-	<0.1	<0.1	-	<0.1	<0.1	<0.1	-	<0.1	<0.1	<0.1	-	1.4	<0.1	<0.1
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	510	281	283	-	-	-	-	-	-	-	-	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	260	143	143	-	-	-	-	-	-	-	-	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	250	138	141	-	-	-	-	-	-	-	-	-	-	-	-
As (total)	µg/L	15.4	15.1	6.1	5.5	29.0	15.8	16.6	15.9	16.2	10.2	9.4	14.3 14.3	14.0 14.5	8.1 8.1	7.8 7.8	20.7	20.5	11.6	10.2
As (soluble)	µg/L	-	-	-	-	15.7	12.6	16.8	-	-	-	-	-	-	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	13.3	3.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	14.0	13.5	15.1	-	-	-	-	-	-	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	1.7	<0.1	1.8	-	-	-	-	-	-	-	-	-	-	-	-
Fe (total)	µg/L	1,449	1,294	291	216	2,478	1,602	1,596	1,512	1,525	930	874	1,169 1,165	1,232 1,274	537 537	469 448	1,535	1,526	901	856
Fe (soluble)	µg/L	-	-	-	-	1,227	NA	1417	-	-	-	-	-	-	-	-	-	-	-	-
Mn (total)	µg/L	17.0	15.7	16.2	15.4	32.9	19.2	19.2	17.8	17.9	17.8	17.4	15.8 15.6	16.1 16.4	16.2 15.9	16.3 15.8	19.1	19.2	19.5	19.7
Mn (soluble)	µg/L	-	-	-	-	19.5	11.8	20.8	-	-	-	-	-	-	-	-	-	-	-	-

(a) Starting 10/11/05, total phosphorous analyzed instead of orthophosphate.

IN = influent; AC = after chlorination; TA = after Vessel A; TB = after Vessel B; TT = after combined effluent. NA = not available.

Analytical Results from Treatment Plant Sampling at Delavan, WI (Continued)

Sampling Date		10/25/05[(a)]			11/01/05				11/08/05				11/15/05				11/29/05		
Sampling Location / Parameter	Unit	IN	AC	TT	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TT
Alkalinity (as $CaCO_3$)	mg/L	352	356	352	352	343	352	348	365	361	361	361	361	352	365	392	352	361	352
Fluoride	mg/L	0.2	0.2	0.2	-	-	-	-	-	-	-	-	-	-	-	-	0.2	0.2	0.2
Sulfate	mg/L	<1	<1	<1	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	<1
Nitrate (as N)	mg/L	<0.05	<0.05	<0.05	-	-	-	-	-	-	-	-	-	-	-	-	<0.05	<0.05	<0.05
Total Kjeldahl Nitrogen	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ammonia (as N)	mg/L	3.0	-	-	-	-	-	-	2.9	2.7	2.8	2.8	2.9	2.8	2.7	2.8	NA	NA	NA
Orthophosphate (as PO_4)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as PO_4)	mg/L	75.2	79.4	14.2	72.6	79.9	<10	<10	70.7	69.3	<10	14.3	74.6	92.1	<10	<10	71.7	59.7	<10
Silica (as SiO_2)	mg/L	13.4	13.8	13.1	14.3	14.4	14.2	14.5	14.0	14.5	14.0	14.0	14.2	14.5	14.1	14.1	14.5	14.6	14.2
Turbidity	NTU	19.0	6.4	11.0	16.0	2.9	0.1	0.1	19.0	2.6	0.4	0.2	16.0	4.8	0.4	0.3	20.0	3.2	<0.1
TOC	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	7.4	7.6	7.4	7.5	7.5	7.5	7.5	7.4	7.6	7.6	7.4	7.4	7.5	7.5	7.4	7.5	7.5	7.4
Temperature	°C	13.1	13.3	13.0	14.6	14.8	14.6	15.0	12.5	13.6	13.3	12.1	14.3	13.1	14.3	14.5	13.5	13.5	14.2
DO	mg/L	2.4	3.6	1.4	2.9	3.8	2.8	2.3	2.3	3.2	2.5	2.2	2.9	3.5	2.4	2.5	3.1	3.5	1.7
ORP	mV	-71	-45	-32	-69	-8	111	113	-85	110	100	102	-69	46	26	98	-49	54	57
Free Chlorine (as Cl_2)	mg/L	-	<0.02	0.03	-	1.50	<0.02	0.7	-	0.5	0.3	0.5	-	0.1	2.3	0.2	-	0.4	0.8
Total Chlorine (as Cl_2)	mg/L	-	<0.1	0.2	-	0.4	1.2	1.0	-	2.8	<0.1	0.8	-	2.4	1.9	1.4	-	0.4	1.8
Total Hardness (as $CaCO_3$)	mg/L	328	338	333	-	-	-	-	-	-	-	-	-	-	-	-	308	311	316
Ca Hardness (as $CaCO_3$)	mg/L	175	184	177	-	-	-	-	-	-	-	-	-	-	-	-	167	174	175
Mg Hardness (as $CaCO_3$)	mg/L	153	154	156	-	-	-	-	-	-	-	-	-	-	-	-	141	138	141
As (total)	µg/L	18.5	20.1	12.7	15.9	17.0	3.4	2.5	22.3	21.6	7.2	6.6	21.3	22.8	3.7	3.1	18.5	18.3	2.6
As (soluble)	µg/L	17.5	15.1	11.6	-	-	-	-	-	-	-	-	-	-	-	-	17.9	8.8	2.6
As (particulate)	µg/L	1.0	4.9	1.1	-	-	-	-	-	-	-	-	-	-	-	-	0.7	9.6	<0.1
As (III)	µg/L	17.2	8.0	9.9	-	-	-	-	-	-	-	-	-	-	-	-	16.7	4.1	1.5
As (V)	µg/L	0.3	7.1	1.8	-	-	-	-	-	-	-	-	-	-	-	-	1.2	4.7	1.1
Fe (total)	µg/L	1,530	1,501	834	1,436	1,590	<25	<25	1,542	1,302	<25	<25	1,606	1,905	<25	<25	1,558	1,531	<25
Fe (soluble)	µg/L	1,480	1,131	832	-	-	-	-	-	-	-	-	-	-	-	-	1,613	444	<25
Mn (total)	µg/L	19.1	19.0	21.0	19.0	20.3	19.2	19.7	17.5	17.1	15.8	16.4	19.6	20.2	18.8	18.9	19.5	19.8	18.9
Mn (soluble)	µg/L	19.2	18.7	20.8	-	-	-	-	-	-	-	-	-	-	-	-	20.2	19.1	19.0

(a) Starting 10/25/05, ammonia (as N) analyzed.

IN = influent; AC = after chlorination; TA = after Vessel A; TB = after Vessel B; TT = after combined effluent. NA = not available.

Analytical Results from Treatment Plant Sampling at Delavan, WI (Continued)

Sampling Date		12/06/05				12/13/05				01/03/06[a]			01/10/06				01/17/06			
Sampling Location / Parameter	Unit	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TT	IN	AC	TA	TB	IN	AC	TA	TB
Alkalinity (as $CaCO_3$)	mg/L	334	348	356	352	361 370	374 374	374 374	370 370	374	374	374	370	334	370	378	374	370	374	374
Fluoride	mg/L	-	-	-	-	-	-	-	-	0.2	0.2	0.2	-	-	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	<1	<1	<1	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	<0.05	<0.05	<0.05	-	-	-	-	-	-	-	-
Total Kjeldahl Nitrogen	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ammonia (as N)	mg/L	2.9	2.8	2.9	2.9	3.0 3.0	2.9 2.9	2.9 3.2	2.9 3.1	3.2	2.9	2.9	3.0	2.9	2.9	2.8	3.0	3.0	2.9	2.9
Orthophosphate (as PO_4)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as PO_4)	mg/L	84.5	82.3	<10	<10	69.1 71.0	68.2 69.5	<10 <10	<10 <10	60.7	59.4	<10	<10	<10	<10	<10	74.2	49.4	<10	<10
Silica (as SiO_2)	mg/L	14.2	14.5	14.2	14.3	14.7 14.4	14.7 14.7	14.9 14.1	14.3 14.0	14.4	13.0	14.3	15.0	14.8	14.4	14.6	15.3	15.2	14.7	14.7
Turbidity	NTU	18.0	2.3	<0.1	0.1	16 .0 19.0	1.9 2.0	0.4 0.1	0.1 0.6	18.0	10.0	0.5	17.0	16.0	2.5	0.6	19.0	2.3	0.7	0.4
TOC	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	7.5	7.5	7.4	7.5	7.5	7.4	7.7	7.5	NA	NA	NA	7.2	7.3	7.3	7.3	7.3	7.5	7.5	7.4
Temperature	°C	12.5	12.2	11.8	11.6	11.8	10.9	12.4	11.2	NA	NA	NA	13.5	13.0	12.9	12.7	13.0	12.6	11.6	11.3
DO	mg/L	2.9	4.1	2.8	3.8	3.6	3.3	2.6	3.9	NA	NA	NA	1.7	1.8	1.4	2.0	1.8	2.7	1.7	1.0
ORP	mV	-46	104	111	116	-45	36	69	67	NA	NA	NA	132	127	128	126	60	66	91	92
Free Chlorine (as Cl_2)	mg/L	-	1.5	3.3	1.4	-	0.8	<0.02	<0.02	-	NA	NA	-	0.2	0.2	<0.02	-	0.7	2.3	2.1
Total Chlorine (as Cl_2)	mg/L	-	4.4	2.9	4.0	-	0.1	0.3	<0.1	-	NA	NA	-	0.1	0.1	<0.1	-	2.7	1.8	0.8
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	330	327	331	-	-	-	-	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	174	171	175	-	-	-	-	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	155	156	156	-	-	-	-	-	-	-	-
As (total)	µg/L	18.6	18.9	2.5	2.9	17.1 17.3	17.5 17.6	3.0 3.0	3.3 3.3	17.4	18.1	4.9	16.4	17.1	6.5	6.2	17.5	17.0	3.2	2.5
As (soluble)	µg/L	-	-	-	-	-	-	-	-	17.5	15.5	4.9	-	-	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	-	-	<0.1	2.6	<0.1	-	-	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	-	-	16.4	9.7	3.9	-	-	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	-	-	1.1	5.8	1.0	-	-	-	-	-	-	-	-
Fe (total)	µg/L	1,388	1,384	<25	<25	1,373 1,445	1,446 1,407	<25 <25	<25 <25	1,438	1,265	<25	1,303	1,340	542	291	1,267	1,278	<25	<25
Fe (soluble)	µg/L	-	-	-	-	-	-	-	-	1,437	1,120	<25	-	-	-	-	-	-	-	-
Mn (total)	µg/L	35.8	18.4	17.7	17.6	18.2 19.3	18.8 18.2	18.5 17.8	19.0 18.3	19.0	18.1	19.3	17.1	17.4	18.0	19.6	18.0	18.1	16.9	16.8
Mn (soluble)	µg/L	-	-	-	-	-	-	-	-	20.0	19.2	20.6	-	-	-	-	-	-	-	-

(a) Onsite water quality parameters not taken because field meter back at Battelle for troubleshooting.

IN = influent; AC = after chlorination; TA = after Vessel A; TB = after Vessel B; TT = after combined effluent. NA = not available.

Analytical Results from Treatment Plant Sampling at Delavan, WI (Continued)

Sampling Date		01/24/06				01/31/06			02/07/06				02/14/06				02/21/06			
Sampling Location Parameter	Unit	IN	AC	TA	TB	IN	AC	TT	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB
Alkalinity (as $CaCO_3$)	mg/L	383	378	374	383	384	359	359	349	357	349	357	358	354	362	358	356 361	356 356	361 361	356 356
Fluoride	mg/L	-	-	-	-	0.2	0.2	0.2	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	<1	<1	<1	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	<0.05	<0.05	<0.05	-	-	-	-	-	-	-	-	-	-	-	-
Total Kjeldahl Nitrogen	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ammonia (as N)	mg/L	3.1	2.9	2.9	3.1	3.0	3.0	2.8	2.9	2.8	3.0	2.8	2.9	2.5	2.7	2.8	3.0 3.0	3.0 2.8	2.7 2.7	2.7 2.7
Orthophosphate (as PO_4)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as PO_4)	mg/L	75.0	75.0	<10	<10	60.1	59.2	<10	77.6	77.0	<10	<10	67.8	66.8	<10	<10	70.3 74.6	73.8 77.3	<10 <10	<10 <10
Silica (as SiO_2)	mg/L	14.9	15.0	14.2	14.4	14.4	14.0	13.8	14.8	14.6	14.9	14.6	14.2	14.4	14.1	13.8	14.7 14.5	14.8 15.0	14.5 15.0	14.6 14.3
Turbidity	NTU	19.0	2.2	NA	0.2	16.0	1.9	0.3	13.0	2.2	1.1	0.2	16.0	4.3	2.3	1.8	21.0 22.0	2.2 2.5	0.6 0.6	0.7 0.7
TOC	mg/L	-	-	-	-	1.7	1.7	1.6	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	7.2	7.4	7.3	7.2	7.3	7.4	7.5	7.2	7.3	7.3	7.2	7.2	7.3	7.4	7.4	7.2	7.4	7.4	7.4
Temperature	ºC	13.4	12.3	13.0	13.8	12.6	12.0	12.1	14.4	13.6	13.4	13.1	12.8	12.1	11.9	11.8	12.9	12.2	11.9	12.3
DO	mg/L	1.0	1.5	4.2	1.4	3.4	4.0	5.4	3.9	2.2	1.7	0.9	2.4	5.0	4.0	1.5	1.8	1.7	1.4	1.3
ORP	mV	102	112	123	118	7	44	69	-17	2	5	10	-82	-76	-72	-71	-87	-22	-10	-2
Free Chlorine (as Cl_2)	mg/L	-	1.5	<0.02	<0.02	-	2.5	2.2	-	2.5	1.7	2.4	-	0.1	0.1	0.3	-	2.1	2.8	1.9
Total Chlorine (as Cl_2)	mg/L	-	0.3	<0.1	<0.1	-	3.8	2.7	-	2.7	1.4	2.4	-	<0.1	<0.1	0.2	-	2.9	3.2	3.3
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	286	285	292	-	-	-	-	-	-	-	-	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	168	168	169	-	-	-	-	-	-	-	-	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	119	117	123	-	-	-	-	-	-	-	-	-	-	-	-
As (total)	μg/L	22.0	21.0	10.5	7.3	17.2	17.1	3.6	25.1	24.3	5.5	3.6	16.0	15.4	4.2	3.5	18.6 19.0	19.7 20.6	2.6 2.7	2.5 2.6
As (soluble)	μg/L	-	-	-	-	15.7	7.7	3.2	-	-	-	-	-	-	-	-	-	-	-	-
As (particulate)	μg/L	-	-	-	-	1.5	9.4	0.4	-	-	-	-	-	-	-	-	-	-	-	-
As (III)	μg/L	-	-	-	-	14.6	2.6	1.3	-	-	-	-	-	-	-	-	-	-	-	-
As (V)	μg/L	-	-	-	-	1.1	5.1	1.9	-	-	-	-	-	-	-	-	-	-	-	-
Fe (total)	μg/L	1,278	1,296	897	363	1,502	1,495	<25	1,304	1,195	<25	<25	1,248	1,241	86	<25	1,426 1,367	1,437 1,407	<25 <25	<25 <25
Fe (soluble)	μg/L	-	-	-	-	1,564	366	<25	-	-	-	-	-	-	-	-	-	-	-	-
Mn (total)	μg/L	18.4	18.3	13.8	17.2	21.0	21.2	19.2	17.9	16.9	18.8	17.0	15.9	16.2	15.7	16.2	18.7 17.9	20.6 19.3	16.7 16.6	16.7 17.0
Mn (soluble)	μg/L	-	-	-	-	21.9	20.8	19.8	-	-	-	-	-	-	-	-	-	-	-	-

Analytical Results from Treatment Plant Sampling at Delavan, WI (Continued)

Sampling Date		02/28/06			03/07/06				03/13/06				03/21/06				03/28/06		
Sampling Location / Parameter	Unit	IN	AC	TT	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TT
Alkalinity (as $CaCO_3$)	mg/L	362	362	354	365	356	356	361	347	356	351	364	356	356	356	361	358	358	358
Fluoride	mg/L	0.2	0.2	0.2	-	-	-	-	-	-	-	-	-	-	-	-	0.2	0.2	0.2
Sulfate	mg/L	<1.0	<1.0	<1.0	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	<1
Nitrate (as N)	mg/L	<0.05	<0.05	<0.05	-	-	-	-	-	-	-	-	-	-	-	-	<0.05	<0.05	<0.05
Total Kjeldahl Nitrogen	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.4	3.1	2.8
Ammonia (as N)	mg/L	2.9	2.8	2.8	3.9	3.5	3.5	3.6	2.3	2.3	2.4	2.2	2.8	2.7	2.7	2.5	2.7	2.4	2.3
Orthophosphate (as PO_4)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as PO_4)	mg/L	77.9	110	<10	61.1	62.6	<10	<10	67.3	61.9	<10	<10	71.0	68.8	<10	<10	74.5	74.4	<10
Silica (as SiO_2)	mg/L	13.8	14.0	14.0	14.4	14.8	13.7	14.0	14.2	14.4	14.3	13.5	14.5	14.3	15.0	14.0	14.7	14.7	14.3
Turbidity	NTU	19.0	2.4	1.0	18.0	2.4	1.4	1.1	17.0	2.3	1.6	1.5	18.0	1.7	0.5	0.3	20.0	3.0	16.0
TOC	mg/L	1.5	1.5	1.5	-	-	-	-	-	-	-	-	-	-	-	-	NA	NA	NA
pH	S.U.	7.3	7.4	7.4	7.4	7.5	7.4	7.4	7.3	7.4	7.3	7.4	NA	NA	NA	NA	7.6	7.5	7.4
Temperature	°C	13.5	12.6	12.1	13.2	12.8	12.0	11.9	13.4	12.7	12.5	12.4	NA	NA	NA	NA	13.6	12.9	12.7
DO	mg/L	2.2	2.8	1.6	2.2	3.1	1.4	1.5	1.9	2.6	2.0	1.6	NA	NA	NA	NA	3.0	2.0	2.3
ORP	mV	-48	54	66	-34	325	330	336	-93	298	333	340	NA	NA	NA	NA	-65	136	-52
Free Chlorine (as Cl_2)	mg/L	-	3.0	3.3	-	3.0	2.4	1.2	-	3.0	1.0	3.6	-	NA	NA	NA	-	0.9	0.1
Total Chlorine (as Cl_2)	mg/L	-	3.3	2.8	-	3.2	2.5	2.5	-	3.3	3.3	3.6	-	NA	NA	NA	-	1.9	<0.1
Total Hardness (as $CaCO_3$)	mg/L	297	297	296	-	-	-	-	-	-	-	-	-	-	-	-	286	292	289
Ca Hardness (as $CaCO_3$)	mg/L	160	158	159	-	-	-	-	-	-	-	-	-	-	-	-	154	154	151
Mg Hardness (as $CaCO_3$)	mg/L	137	139	137	-	-	-	-	-	-	-	-	-	-	-	-	132	138	138
As (total)	µg/L	21.0	27.6	2.8	18.5	19.1	2.3	2.4	21.6	19.5	2.9	2.9	20.8	20.4	3.4	3.4	19.6	20.2	7.7
As (soluble)	µg/L	17.9	7.6	2.5	-	-	-	-	-	-	-	-	-	-	-	-	17.9	8.7	6.9
As (particulate)	µg/L	3.1	20.0	0.3	-	-	-	-	-	-	-	-	-	-	-	-	1.7	11.4	0.8
As (III)	µg/L	16.9	4.0	1.3	-	-	-	-	-	-	-	-	-	-	-	-	16.5	3.8	5.5
As (V)	µg/L	1.0	3.5	1.2	-	-	-	-	-	-	-	-	-	-	-	-	1.4	4.9	1.4
Fe (total)	µg/L	1,252	2,170	<25	1,420	1,410	<25	<25	1,365	1,371	<25	<25	1,361	1,376	<25	<25	1,552	1,576	1,120
Fe (soluble)	µg/L	1,296	223	<25	-	-	-	-	-	-	-	-	-	-	-	-	1,615	474	NA
Mn (total)	µg/L	18.7	17.8	16.7	19.1	18.6	18.2	18.2	18.5	18.3	18.7	18.3	19.7	19.9	19.9	19.5	36.7	19.8	19.1
Mn (soluble)	µg/L	17.7	16.8	16.8	-	-	-	-	-	-	-	-	-	-	-	-	32.4	18.6	21.5

Analytical Results from Treatment Plant Sampling at Delavan, WI (Continued)

Sampling Date		04/04/06				04/11/06				04/18/06				04/25/06			05/02/06			
Sampling Location / Parameter	Unit	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TT	IN	AC	TA	TB
Alkalinity (as $CaCO_3$)	mg/L	349	353	357	361	369	378	374	374	378	378	374	382	364	356	356	362	367	354	367
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	0.2	0.1	0.2	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	<1	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.05	<0.05	0.1	-	-	-	-
Total Kjeldahl Nitrogen	mg/L	2.7	2.6	2.8	3.0	2.9	2.0	2.8	3.0	3.0	2.9	3.1	3.1	-	-	-	-	-	-	-
Ammonia (as N)	mg/L	3.0	2.7	2.7	2.9	3.0	2.8	2.8	2.8	3.4	3.2	3.1	3.0	3.0	3.7	2.8	2.9	2.6	2.5	2.9
Orthophosphate (as PO_4)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as PO_4)	mg/L	75.4	76.5	<10	<10	67.4	66.0	<10	<10	77.0	75.1	<10	<10	75.1	68.9	69.1	59.4	60.1	58.0	<10
Silica (as SiO_2)	mg/L	14.9	14.2	14.4	14.2	13.9	13.4	13.6	14.2	14.4	14.4	14.1	14.1	14.3	13.9	15.1	15.4	15.1	15.3	14.9
Turbidity	NTU	20.0	2.1	0.5	0.3	18.0	2.6	2.2	3.8	16.0	7.9	0.2	0.7	16.0	1.8	1.7	12.0	8.8	9.1	5.1
TOC	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	7.4	7.5	7.4	7.4	7.3	7.4	7.4	7.4	7.3	7.3	7.3	7.3	8.0	8.0	8.0	8.1	8.1	8.1	8.0
Temperature	℃	12.8	12.4	12.3	12.3	14.6	13.9	13.8	13.8	12.5	12.1	11.9	11.9	14.5	13.5	12.2	13.4	12.5	12.3	12.4
DO	mg/L	4.7	3.2	1.7	1.1	2.9	2.4	2.1	2.2	1.8	1.8	1.4	1.5	3.1	1.4	1.2	3.4	3.2	3.6	2.0
ORP	mV	-86	195	185	194	-19	221	195	182	190	-51	-28	-26	-50	248	282	-73	-75	-74	-71
Free Chlorine (as Cl_2)	mg/L	-	0.1	0.02	0.4	-	0.8	0.02	0.1	-	<0.02	0.1	0.04	-	0.3	0.9	-	0.1	0.1	0.1
Total Chlorine (as Cl_2)	mg/L	-	3.5	0.1	1.5	-	3.9	0.6	0.6	-	0.33	0.1	0.2	-	3.4	4.0	-	0.5	0.2	0.1
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	310	302	310	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	175	171	174	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	135	131	136	-	-	-	-
As (total)	µg/L	16.6	21.4	6.5	5.8	19.7	19.9	7.0	5.8	18.8	18.6	5.2	4.6	19.5	16.2	16.5	16.8	16.2	16.7	5.1
As (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	16.1	5.6	5.3	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	3.4	10.6	11.2	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	14.2	1.9	1.4	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	1.9	3.8	3.8	-	-	-	-
Fe (total)	µg/L	1,370	1,286	<25	<25	1,448	1,424	455	317	1,439	1,436	<25	102	1,525	1,429	1,400	1,265	1,280	1,280	222
Fe (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	1,403	180	157	-	-	-	-
Mn (total)	µg/L	17.7	17.3	17.8	17.6	18.7	18.2	13.0	14.0	19.1	19.1	16.5	16.7	19.9	18.8	19.2	17.1	17.1	17.4	17.6
Mn (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	19.1	18.9	18.7	-	-	-	-

Analytical Results from Treatment Plant Sampling at Delavan, WI (Continued)

Sampling Date		05/09/06				05/15/06				05/23/06			05/30/06				06/06/06			
Sampling Location Parameter	Unit	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TT	IN	AC	TA	TB	IN	AC	TA	TB
Alkalinity (as $CaCO_3$)	mg/L	343	359	355	380	343 359	359 347	355 363	372 368	359	363	359	353	357	357	357	363	351	359	359
Fluoride	mg/L	-	-	-	-	-	-	-	-	0.2	0.2	0.2	-	-	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	<1	<1	<1	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	<0.01	0.01	<0.01	-	-	-	-	-	-	-	-
Total Kjeldahl Nitrogen	mg/L	-	-	-	-	-	-	-	-	<0.05	0.01	<0.05	-	-	-	-	-	-	-	-
Ammonia (as N)	mg/L	3.2	2.7	2.8	2.8	2.8 2.7	2.8 2.7	2.7 2.7	2.7 2.7	2.4	2.8	2.9	3.0	2.8	2.9	2.9	2.8	2.7	2.6	2.6
Orthophosphate (as PO_4)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as PO_4)	mg/L	83.5	79.2	<10	<10	52.0 52.1	52.6 53.3	<10 <10	<10 <10	65.8	76.4	<10	89.8	85.9	24.9	24.9	63.1	64.5	10.5	<10
Silica (as SiO_2)	mg/L	15.3	14.4	14.5	15.0	14.9 14.8	14.6 14.2	14.5 15.3	14.9 14.5	14.4	14.7	14.5	14.9	14.3	14.2	14.3	14.9	14.8	14.8	14.5
Turbidity	NTU	17.0	5.4	4.0	0.9	17.0 15.0	2.8 2.5	0.3 0.5	0.6 0.4	14.0	5.7	0.5	17.0	12.0	1.5	3.8	16.0	2.0	1.3	2.2
TOC	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	8.0	8.0	8.0	8.0	8.1	8.1	8.1	8.1	7.4	7.5	7.5	7.4	7.4	7.4	7.4	7.3	7.4	7.4	7.3
Temperature	℃	13.5	13.2	12.3	12.1	14.9	14.4	13.5	13.3	14.7	13.0	12.6	11.9	14.4	14.0	13.8	13.9	13.6	13.4	13.4
DO	mg/L	2.4	1.4	1.3	1.1	2.8	1.9	1.4	1.4	1.9	1.8	1.4	2.4	2.3	1.5	1.9	2.1	2.4	2.9	1.6
ORP	mV	-77	-82	-70	-62	-82	-21	159	236	-94	-25	-22	-80	-82	-45	-34	-82	188	145	-16
Free Chlorine (as Cl_2)	mg/L	-	<0.02	0.1	0.1	-	0.3	0.4	0.1	-	0.2	0.1	-	0.03	0.1	0.1	-	0.4	<0.02	<0.02
Total Chlorine (as Cl_2)	mg/L	-	0.1	0.2	<0.1	-	0.7	1.3	2.4	-	0.7	0.1	-	0.3	0.1	0.1	-	3.0	0.1	<0.1
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	262	314	311	-	-	-	-	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	132	162	158	-	-	-	-	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	131	151	153	-	-	-	-	-	-	-	-
As (total)	µg/L	19.8	19.7	7.8	5.3	16.7 16.1	16.4 16.7	5.1 5.0	4.5 4.3	20.7	21.4	6.9	15.1	15.9	4.6	6.2	18.1	16.2	5.6	5.6
As (soluble)	µg/L	-	-	-	-	-	-	-	-	19.6	13.6	6.5	-	-	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	-	-	1.1	7.8	0.4	-	-	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	-	-	15.9	5.2	3.9	-	-	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	-	-	3.7	8.5	2.6	-	-	-	-	-	-	-	-
Fe (total)	µg/L	1,343	1,337	495	218	1,484 1,400	1,377 1,314	<25 <25	<25 <25	1,040	1,342	<25	1,176	1,163	160	312	1,240	1,195	64	215
Fe (soluble)	µg/L	-	-	-	-	-	-	-	-	1,248	661	<25	-	-	-	-	-	-	-	-
Mn (total)	µg/L	21.2	20.0	21.4	22.8	18.9 18.0	18.1 18.3	18.7 18.1	18.4 18.1	16.2	16.5	19.6	15.4	16.1	15.6	15.1	18.1	16.6	20.8	19.0
Mn (soluble)	µg/L	-	-	-	-	-	-	-	-	17.3	16.1	19.6	-	-	-	-	-	-	-	-

Analytical Results from Treatment Plant Sampling at Delavan, WI (Continued)

Sampling Date		06/12/06				06/20/06			06/27/06				07/13/06				07/18/06		
Sampling Location Parameter	Unit	IN	AC	TA	TB	IN	AC	TT	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TT
Alkalinity (as $CaCO_3$)	mg/L	363	368	372	347	359	363	351	364	352	352	364	364	360	356	369	353	361	361
Fluoride	mg/L	-	-	-	-	0.2	0.2	0.2	-	-	-	-	-	-	-	-	0.2	0.2	0.2
Sulfate	mg/L	-	-	-	-	<1	<1	<1	-	-	-	-	-	-	-	-	<1	<1	<1
Nitrate (as N)	mg/L	-	-	-	-	<0.05	<0.05	<0.05	-	-	-	-	-	-	-	-	<0.05	<0.05	<0.05
Total Kjeldahl Nitrogen	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ammonia (as N)	mg/L	2.9	2.4	2.5	2.1	2.4	2.1	2.5	2.7	2.5	2.7	2.8	2.5	3.0	3.0	3.0	2.9	2.7	2.8
Orthophosphate (as PO_4)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as PO_4)	mg/L	91.2	83.4	<10	<10	73.0	78.3	<10	74.9	78.7	<10	<10	62.3	65.1	<10	<10	78.4	74.3	<10
Silica (as SiO_2)	mg/L	14.9	15.6	14.4	15.3	15.4	15.2	15.0	15.0	14.8	15.8	15.4	13.6	13.7	14.1	14.1	13.8	13.9	13.5
Turbidity	NTU	13.4	1.4	0.4	0.5	11.0	1.7	1.2	10.0	9.4	4.9	4.0	15.0	4.6	2.7	1.9	14.0	1.6	3.1
TOC	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	7.3	7.4	7.4	7.5	7.4	7.4	7.4	7.6	7.5	7.4	7.3	7.5	7.4	7.4	7.5	7.4	7.4	7.6
Temperature	℃	15.0	14.1	13.6	13.5	15.9	14.3	13.7	14.5	14.0	13.8	13.8	14.5	14.3	14.1	13.8	14.1	13.6	14.0
DO	mg/L	2.0	1.5	2.0	2.0	2.1	1.8	1.4	6.7	3.3	4.4	1.7	6.4	1.0	1.3	0.8	4.0	1.5	2.1
ORP	mV	-76	258	236	264	-47	232	220	-48	-66	-29	-42	-64	130	173	192	-46	25	144
Free Chlorine (as Cl_2)	mg/L	-	1.8	0.8	1.7	-	1.5	<0.02	-	<0.02	0.1	<0.02	-	0.04	0.3	0.4	-	<0.02	0.05
Total Chlorine (as Cl_2)	mg/L	-	6.4	1.9	4.7	-	5.3	2.9	-	0.1	<0.1	<0.1	-	1.7	1.3	1.4	-	0.8	1.0
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	337	357	365	-	-	-	-	-	-	-	-	322	297	258
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	173	185	191	-	-	-	-	-	-	-	-	169	156	132
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	163	172	173	-	-	-	-	-	-	-	-	153	141	126
As (total)	µg/L	25.3	23.2	5.5	5.3	18.2	17.8	4.2	18.6	19.2	7.6	6.1	18.7	18.9	5.5	5.0	21.3	20.5	4.5
As (soluble)	µg/L	-	-	-	-	18.3	8.1	4.2	-	-	-	-	-	-	-	-	17.5	11.4	4.7
As (particulate)	µg/L	-	-	-	-	<0.1	9.7	<0.1	-	-	-	-	-	-	-	-	3.9	9.1	<0.1
As (III)	µg/L	-	-	-	-	15.4	3.0	1.5	-	-	-	-	-	-	-	-	17.5	5.6	2.1
As (V)	µg/L	-	-	-	-	2.9	5.1	2.8	-	-	-	-	-	-	-	-	<0.1	5.8	2.7
Fe (total)	µg/L	1,184	1,143	75	<25	1,224	1,375	164	1,359	1,409	504	397	997	1,072	<25	<25	1,142	1,155	<25
Fe (soluble)	µg/L	-	-	-	-	1,329	302	155	-	-	-	-	-	-	-	-	1,353	516	<25
Mn (total)	µg/L	18.0	17.1	9.4	15.7	16.7	17.8	15.7	19.8	19.4	23.4	23.0	19.2	17.1	15.4	15.8	16.5	17.3	18.3
Mn (soluble)	µg/L	-	-	-	-	17.8	17.1	15.6	-	-	-	-	-	-	-	-	17.0	16.7	18.8

Analytical Results from Treatment Plant Sampling at Delavan, WI (Continued)

Sampling Date		08/01/06				08/15/06				08/29/06		
Sampling Location / Parameter	Unit	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TT
Alkalinity (as $CaCO_3$)	mg/L	357	357	353	361	354	337	362	358	377	370	390
Fluoride	mg/L	-	-	-	-	-	-	-	-	0.1	0.1	0.1
Sulfate	mg/L	-	-	-	-	-	-	-	-	<1	<1	<1
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	<0.05	<0.05	<0.05
Total Kjeldahl Nitrogen	mg/L	-	-	-	-	-	-	-	-	-	-	-
Ammonia (as N)	mg/L	2.7	2.8	2.9	2.7	NA	0.5	0.5	0.6	3.1	3.3	2.9
Orthophosphate (as PO_4)	mg/L	-	-	-	-	-	-	-	-	-	-	-
Total P (as PO_4)	mg/L	72.1	75.3	<10	<10	72.7	75.0	19.0	<10	84.3	102	<10
Silica (as SiO_2)	mg/L	16.7	16.5	16.4	16.5	14.3	14.1	14.0	13.9	13.6	14.2	13.9
Turbidity	NTU	14.0	4.0	0.2	0.2	15.0	2.8	0.2	0.5	18.0	2.0	0.4
TOC	mg/L	-	-	-	-	-	-	-	-	1.7	1.7	1.9
pH	S.U.	7.2	7.3	7.3	7.3	7.1	7.2	7.2	7.3	7.3	7.4	7.4
Temperature	°C	15.1	14.7	14.6	14.6	13.9	13.5	13.5	13.3	15.3	15.0	14.9
DO	mg/L	1.9	1.7	1.4	1.9	2.1	1.6	1.7	1.7	1.7	2.4	1.4
ORP	mV	-68	-20	122	189	-79	-18	-19	-13	-62	63	83
Free Chlorine (as Cl_2)	mg/L	-	0.2	0.2	0.4	-	0.1	<0.02	0.1	-	<0.02	0.2
Total Chlorine (as Cl_2)	mg/L	-	1.5	1.1	1.7	-	<0.1	0.3	<0.1	-	1.8	2.6
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	338	339	340
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	194	195	191
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	144	144	149
As (total)	µg/L	23.6	25.3	4.2	5.7	18.2	17.6	3.9	3.6	22.8	27.1	4.2
As (soluble)	µg/L	-	-	-	-	-	-	-	-	18.5	9.3	3.4
As (particulate)	µg/L	-	-	-	-	-	-	-	-	4.3	17.8	0.7
As (III)	µg/L	-	-	-	-	-	-	-	-	16.2	4.7	1.1
As (V)	µg/L	-	-	-	-	-	-	-	-	2.3	4.5	2.4
Fe (total)	µg/L	1,210	1,263	<25	<25	1,315	1,208	<25	<25	1,848	2,010	<25
Fe (soluble)	µg/L	-	-	-	-	-	-	-	-	1,846	347	<25
Mn (total)	µg/L	17.0	16.7	17.6	16.9	17.9	17.2	16.6	15.4	21.8	19.5	18.5
Mn (soluble)	µg/L	-	-	-	-	-	-	-	-	22.0	18.7	18.9